HAVE WE FOUND THE FIRST EXOMOON?

ALL ABOUT SPACE™

ISSUE 140
MARCH 2023

ANDROMEDA
CARTWHEEL GALAXIES
SATURN'S RINGS
EXOPLANETS
GIANT LAVA RIVERBED
DIAMOND PLANETS
AURORAE

100 WONDERS *of the* UNIVERSE

THE DISCOVERIES AND INCREDIBLE PHENOMENA THAT HAVE REVOLUTIONISED OUR UNDERSTANDING OF THE COSMOS

HISTORY OF SPACESUITS

FUTURE
ISSUE 140

GALAXIES, NEBULAE & STAR CLUSTERS: MARCH'S ULTIMATE DEEP-SKY TOUR
HEROES OF SPACE: ALEXEI LEONOV / WHY STARS WANDER / OUTER-SPACE OBSERVATORY

Advertisement

Could you save on your household bills?

If you're looking for an easy way to save money on your household bills, what better way than to compare prices and policies with GoCompare.

From car insurance and home insurance, to travel insurance and broadband, you can compare quotes for over 40 products. Now that's something to sing and dance about.

GoCompare

All About Space and GoCompare.com are both Future Plc brands

WELCOME

ISSUE 140

SCAN HERE TO GET OUR DAILY NEWSLETTER

The universe is full of wonders – from the ordinary to the truly weird and wacky. This issue, we present a hundred of our favourites, including the iconic Pillars of Creation, the methane seas of Titan, acidic atmosphere of Venus, volcanoes on Mars, diamond planets, cosmic microwave background radiation, pulsars and the very first Hubble Deep Field.

This month, we're also getting you prepared to 'run' the Messier marathon, an activity to see how many galaxies, nebulae and star clusters you can spot in a night. There are 110 across the Northern Hemisphere forming the catalogue initially composed by French astronomer Charles Messier. Let us know how you get on – you only need to use your unaided eyes to get started. And if you really want to complete the marathon but don't have a telescope, we're offering you the chance to win a Sky-Watcher Skyhawk-114.

Enjoy the issue, I'll see you next time for more tours of our amazingly wonderful universe.

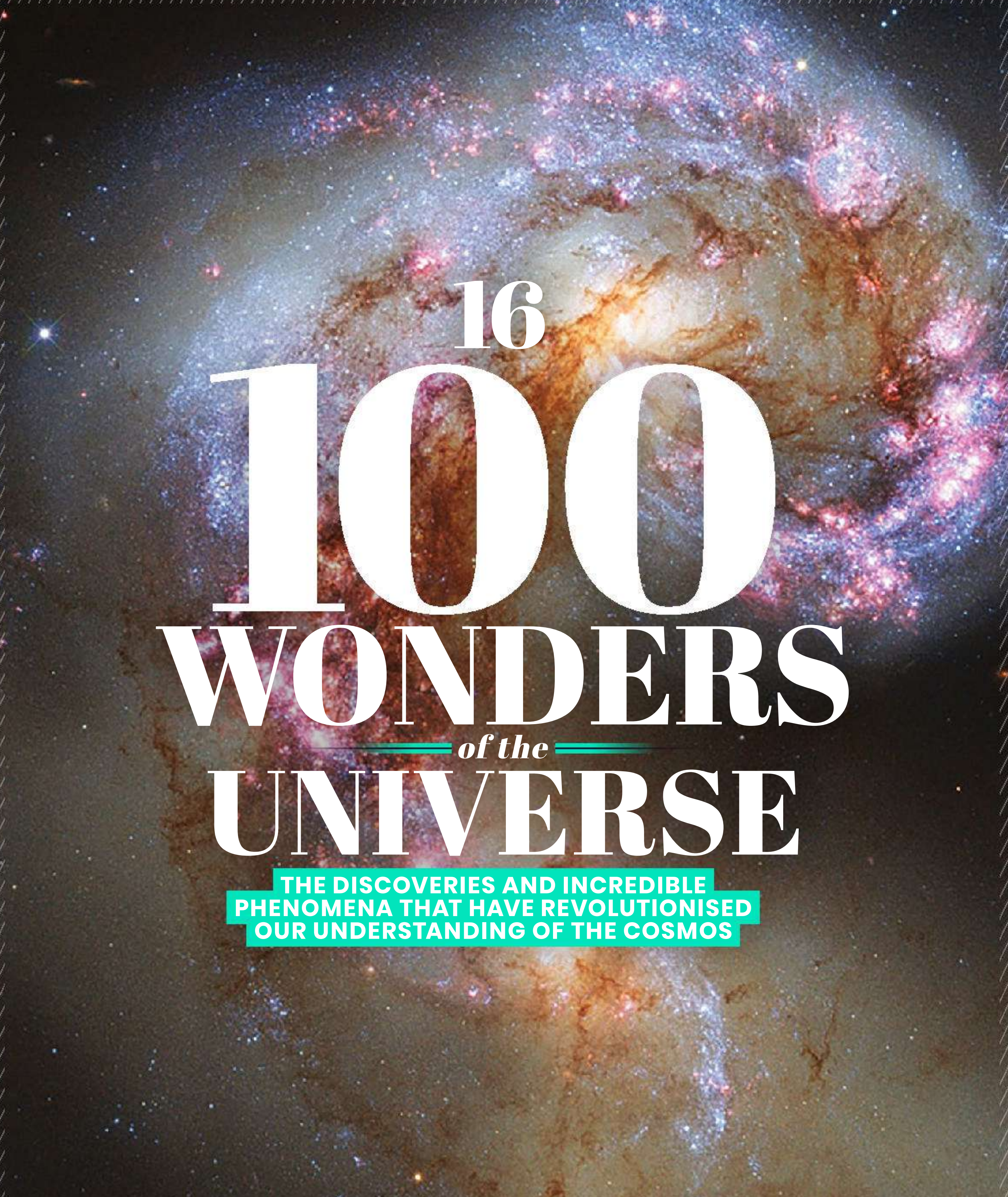
GEMMA LAVENDER
Content Director

38 Subscribe to All About Space today and you'll receive

✔ **Great savings off the cover price**
✔ Every issue delivered straight to your door or digital device before it arrives in the shops
✔ **Exclusive subscriber-edition covers**

ALL ABOUT SPACE
ISSUE 141
ON SALE
23 MARCH

KEEP IN TOUCH /AllAboutSpaceMagazine @spaceanswers space@spaceanswers.com



16

100 WONDERS of the UNIVERSE

THE DISCOVERIES AND INCREDIBLE PHENOMENA THAT HAVE REVOLUTIONISED OUR UNDERSTANDING OF THE COSMOS

LAUNCHPAD

06 News from around the universe

FUTURE TECH

30 Deep-orbit observatory
We can use the Sun as a giant lens, but we'd need to send a telescope far into the Solar System

INTERVIEW

32 Alex Teachey
Sifting through data from Kepler, astronomers believe that we could have picked up the first signal of an alien moon

FOCUS ON

36 NASA's asteroid-hunting telescope
The infrared space telescope will search for potentially threatening near-Earth objects

40 History of spacesuits
These miniature spacecraft have allowed us to operate in space for over half a century

FOCUS ON

49 The first galaxies may have formed earlier than we thought
The finding has been revealed by the James Webb Space Telescope

FOCUS ON

50 Webb scores its first rocky planet confirmation
Hopefully the first of many more detections to come

52 NASA inventions in your home
NASA has an obligation to foster and transfer its technological and scientific breakthroughs to the public and commercial spheres

INSTANT EXPERT

58 How high could we jump on other worlds?
What is low gravity like?

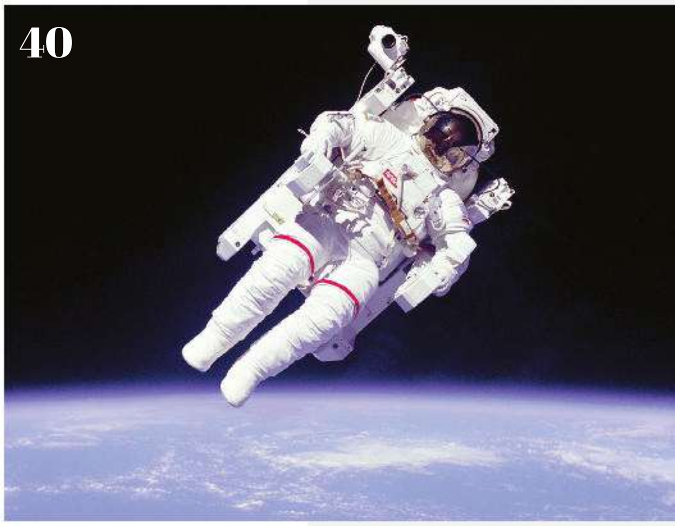
60 Rogue stars
Scientists have been studying a ghostly light in between galaxies to discover the origin of these unusual stellar objects

FOCUS ON

66 Rare binary system
Gaia17bpp began brightening again after a seven-year eclipse

68 Ask Space
Your questions answered by our panel of experts

72 Messier marathon
This March there are galaxies, nebulae and star clusters galore


40

32

STARGAZER

78 What's in the sky?

80 Planetarium

82 Month's planets

84 Moon tour

85 Naked eye & binocular targets

86 Deep sky challenge

88 The Northern Hemisphere

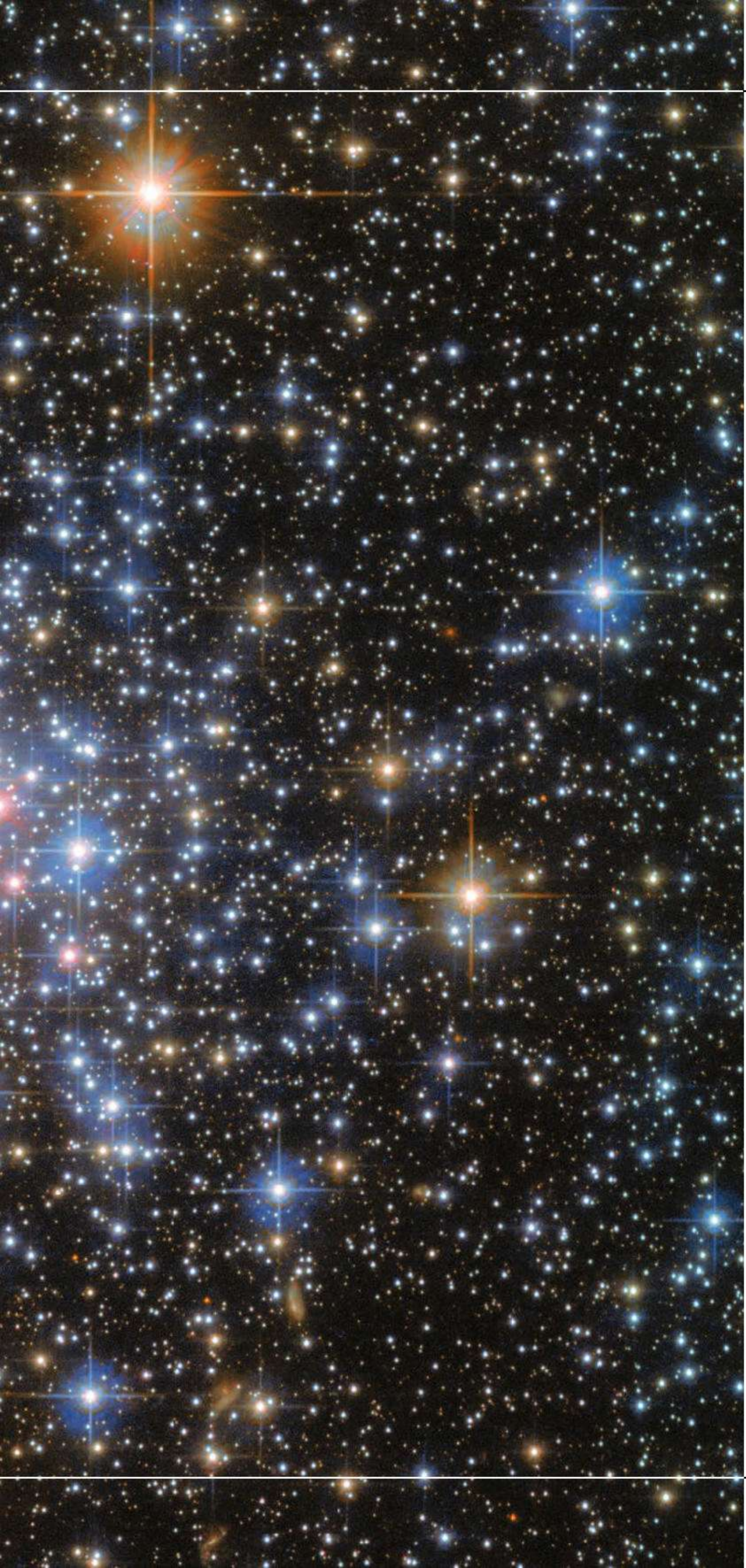
90 Astrophotos

92 Review

96 In the shops

60

WIN!
SKY-WATCHER SKYHAWK-114
WORTH £169
15



9 December 2022

Hubble captures a glittering neighbour

A dazzling new image from the Hubble Space Telescope captures a stunning view of a nearby open cluster of stars that is slowly dissolving into the dwarf galaxy around it. The photo shows part of the Small Magellanic Cloud, a dwarf galaxy of the Milky Way that is just 200,000 light years from Earth and is the smaller partner of the slightly closer Large Magellanic Cloud, also a neighbouring dwarf galaxy. Its proximity lets us observe it in such great detail that the Hubble Space Telescope can see a relatively tiny gathering of stars with remarkable clarity.

The new photo shows only a small portion of the Small Magellanic Cloud – an open cluster designated NGC 376. An open cluster is distinguished from a globular cluster by its more open, loosely bound structure, allowing us to identify individual stars even in its most tightly packed regions. Globular clusters, by contrast, are so dense that stars can be within a single light year of each other, and the light from the stars in their central regions blends together. Although the Small Magellanic Cloud contains hundreds of millions of stars, NGC 376 is only about 3,400 solar masses, so it is considerably less massive than the Small Magellanic Cloud itself. Located in the southern sky constellation of Tucana, NGC 376 was first discovered in 1826 by Scottish astronomer James Dunlop.

© ESA/Hubble; NASA

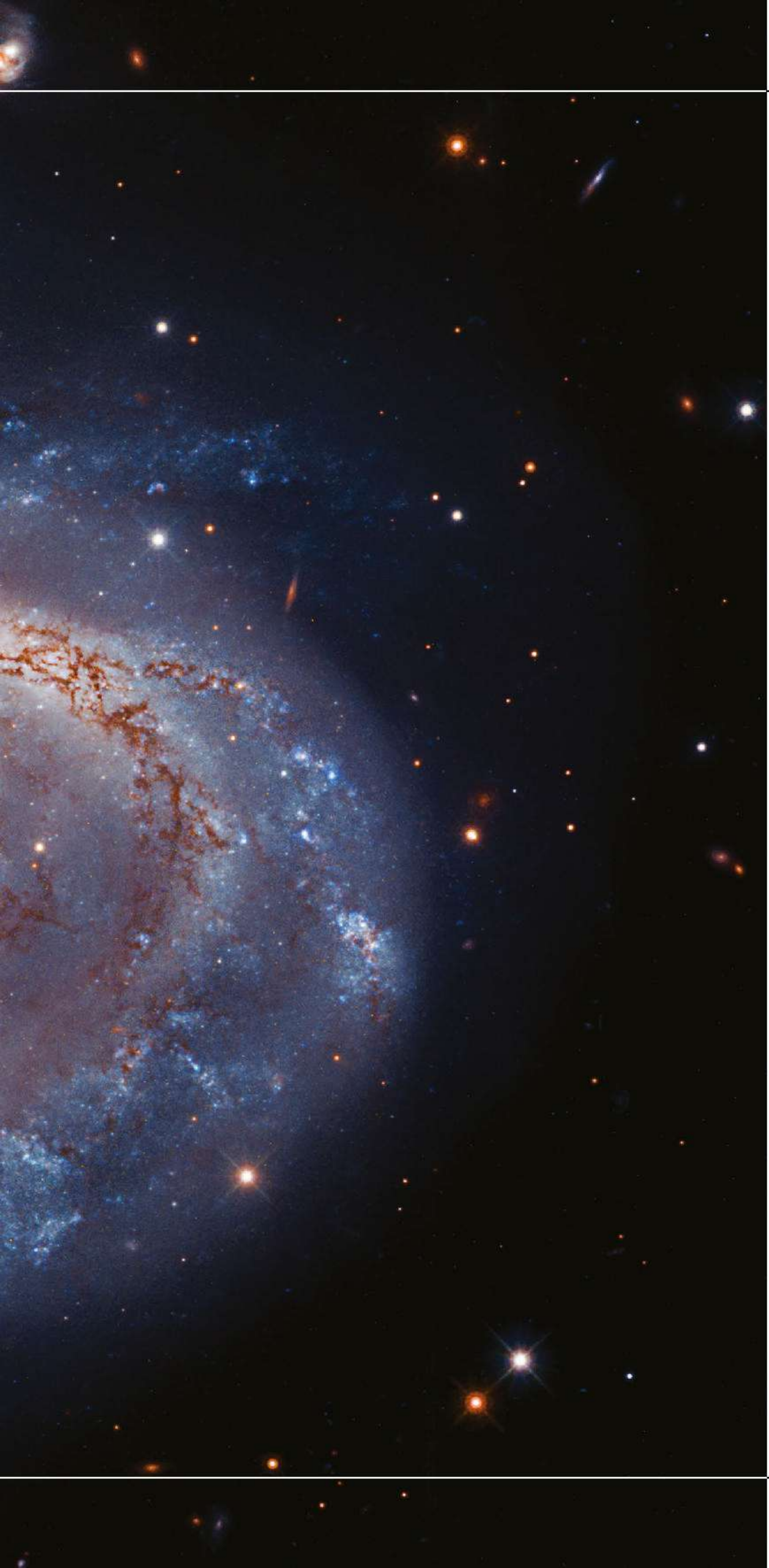
30 November 2022

A galactic get together

The James Webb Space Telescope has captured a pair of galaxies distorting each other as they merge in a great galactic get together. The ongoing cosmic collision imaged by Webb is known as ZW II 96. It's roughly 500 million light years from Earth and located in the constellation of Delphinus. The image was created by Webb bringing to bear its cutting-edge Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) payloads on ZW II 96 and details how the shape of both galaxies are being distorted by their respective gravitational attraction.

The observation is part of a wider effort by Webb to examine how galaxies evolve, focusing particularly on nearby so-called luminous infrared galaxies. These galaxies – of which ZW II 96 is an example – are particularly bright at infrared wavelengths, with luminosities more than 100 billion times that of the Sun. Merging galaxy system ZW II 96 is well known to astronomers and has been observed previously by the Hubble Space Telescope and ground-based telescopes.

© ESA/Webb; NASA



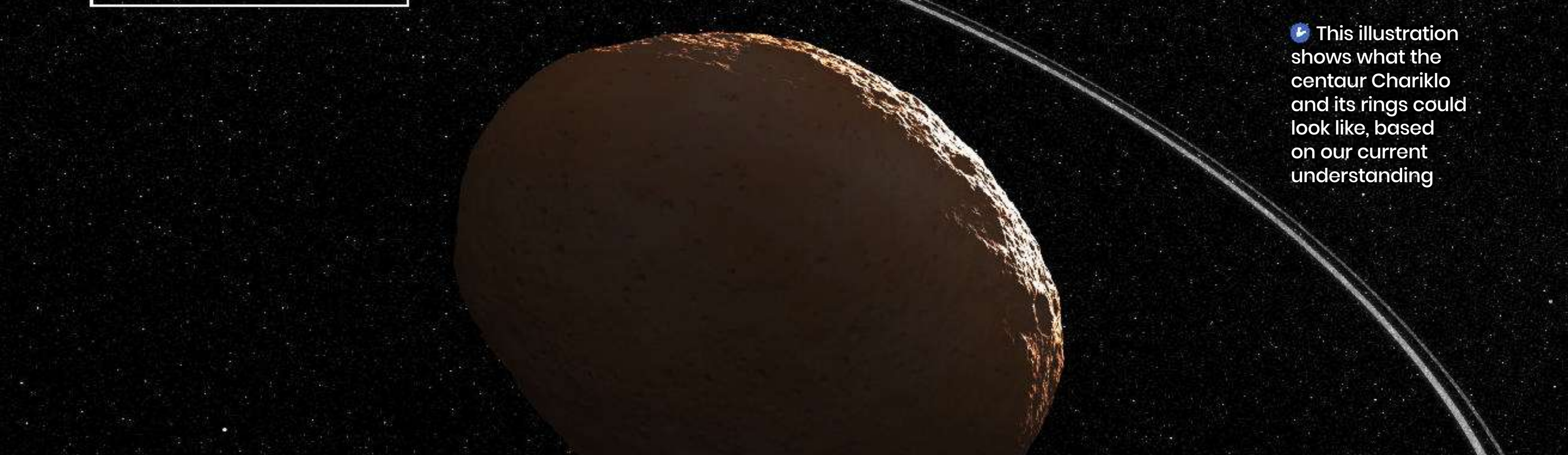
15 December 2022

A model galaxy

While the James Webb Space Telescope is getting a lot of press lately, its predecessor Hubble continues to impress – this time by snapping the galaxy NGC 6956, a near-perfect example of a barred galaxy located about 214 million light years from Earth. Barred galaxies, which get their name from the very prominent 'bar' of stars that cuts across the galactic nucleus, are among the most common types of galaxies in the known universe, making up an estimated 70 per cent of all galaxies. Bar structures are also far more common in galaxies with active galactic nuclei, as gas and other material is fed in towards the galactic core along these bars.

This process helps to eventually destabilise the bar. However, the more mass that's funnelled to the galactic core, the more unstable the bar becomes, eventually softening the bar into the more traditional spiral formation that most people think of when thinking of a spiral galaxy. This most recent photo of NGC 6956 was taken to look at Cepheid variable stars, which are stars whose luminosity cycles between bright and dim at regular intervals. These periods of brightening and dimming are directly related to a star's actual brightness, and we're able to calculate these variations in apparent brightness to the stars' actual brightness, allowing us to determine their distance from us.

© NASA; ESA;



This illustration shows what the centaur Chariklo and its rings could look like, based on our current understanding

Webb discovers water ice at ringed asteroid Chariklo by remarkable luck

Reported by Sharmila Kuthunur

The most comprehensive plans need a sprinkle of luck, even in space. In October 2022 the James Webb Space Telescope watched as Chariklo, a tiny ringed asteroid, eclipsed a star. This event, called an occultation, marked a first for Webb. At the month's end, Webb turned towards Chariklo again and notched another victory: For the first time, astronomers analysing the telescope's data spotted clear signs of water ice, the presence of which was only hinted at until now. These observations will guide astronomers to better understand the nature and behaviour of tiny bodies in the outer reaches of our Solar System. But the two feats almost didn't happen.

Although it's the largest of its kind, Chariklo is still too small and too far for even the mighty Webb to photograph directly. Instead, astronomers decided to study it through occultation, which is an indirect but powerful method to study small bodies like Chariklo. But the team didn't know if and when a star – without which an occultation would not occur – would fall into Webb's field of view. This made Chariklo part of Webb's target of opportunity program: if the asteroid happened to cross in front of a star, the program would allow astronomers to temporarily interrupt the telescope's schedule to observe the event.

The team calculated only a 50 per cent chance that Webb would spot a star bright enough with an interesting object like Chariklo crossing in front. After its launch in 2021, as Webb went through routine course corrections to hold it steady in its parking spot in space, the team continued predicting and revising its list of possible occultations. Late last year, astronomers ended up on the favourable side of that 50 per cent when they discovered, "by remarkable good luck," that Chariklo was on track to occult a star that also fell into Webb's view. "This was the first stellar occultation attempted with Webb," the team said. "A lot of hard work went into identifying and refining the predictions for this unusual event."

On 18 October 2022, Chariklo and its system of two rings crossed in front of a star. Using Webb's Near-infrared Camera (NIRCam), astronomers monitored the star's brightness for an hour. The resulting data showed two dips in the star's brightness, as expected – when the asteroid's rings first hid the star as the eclipse began, and again when the last of its rings wrapped up the occultation. "The shadows produced by Chariklo's rings were clearly detected," the team said, "demonstrating a new way of using Webb to explore Solar System objects."

Objects like Chariklo are called centaurs thanks to their hybrid nature. They look like asteroids but behave like comets – complete with visible tails. Their home, an unstable orbit between Jupiter and Neptune, hosts thousands of centaurs of varying shapes and sizes. As interesting as they are, their small sizes and vast distances make them difficult to study. The composition of even the biggest centaur, Chariklo – which is still tiny at just 250 kilometres (160 miles) in diameter and distant at a whooping 3.2 billion kilometres (2 billion miles) away from us – is poorly understood. Also, past research hinted at water ice somewhere in Chariklo's system, but had yet to conclusively detect it.

In this latest research, astronomers pointed Webb at Chariklo again. This time, they used the telescope's Near-infrared Spectrograph (NIRSpec) to measure the sunlight reflected by Chariklo and its two rings. The resulting spectrum showed three absorption bands of water ice, marking the first clear indication of crystalline ice. The presence of crystalline ice likely indicates that Chariklo is subject to constant bombardment, according to Dean Hines, an astronomer at the Space Telescope Science Institute in Maryland. "Because high-energy particles transform ice from crystalline into amorphous states, detection of crystalline ice indicates that the Chariklo system experiences continuous micro-collisions that either expose pristine material or trigger crystallisation processes," Hines said.

Astronomers have gotten one step closer to studying the Chariklo system, but there is still much that remains unknown about the centaur. The spectrum analysed in the latest research includes information about the system as a whole, but at the moment it's difficult to distinguish the data between Chariklo and its two rings.

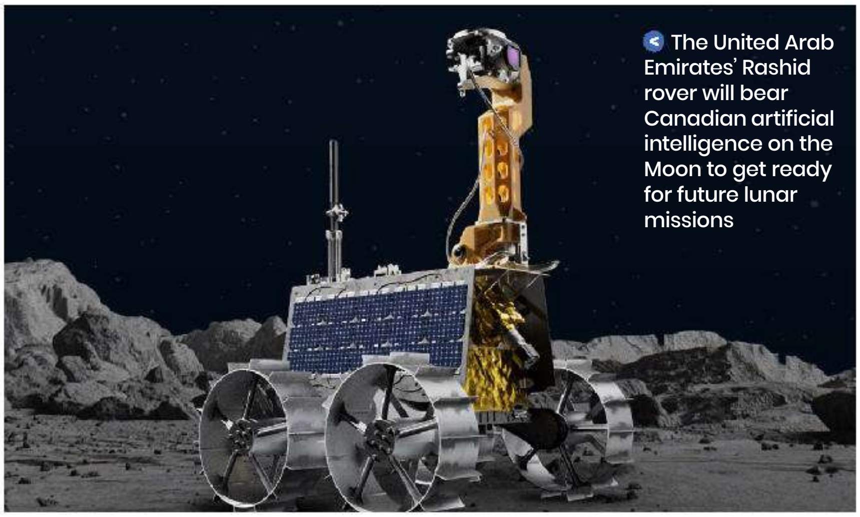
UAE lunar rover will test the first artificial intelligence on the Moon with Canada

Reported by Elizabeth Howell

The Moon is about to host one giant leap in artificial intelligence (AI). A Canadian machine-learning system will make its way to the Moon's surface on board a United Arab Emirates rover that launched with SpaceX on 11 December. The Rashid rover, hosted on the Japanese ispace lander, is expected to touch down this spring in search of minerals and other items of interest on the lunar surface. Canada's system will inform the rover's decision-making in a big first for AI. If this works, the technology will be big for NASA's Moon push, said Mission Control Space Services (MCSS) CEO Ewan Reid. "AI will be a critical enabling tool to making decisions on board spacecraft," Reid said. That work not only extends to seeking out water on the Moon, which NASA plans to do with its Artemis missions, but also to making Earth observation more efficient. And MCSS, a company of just 40 people so far, aims to be in the driver's seat.

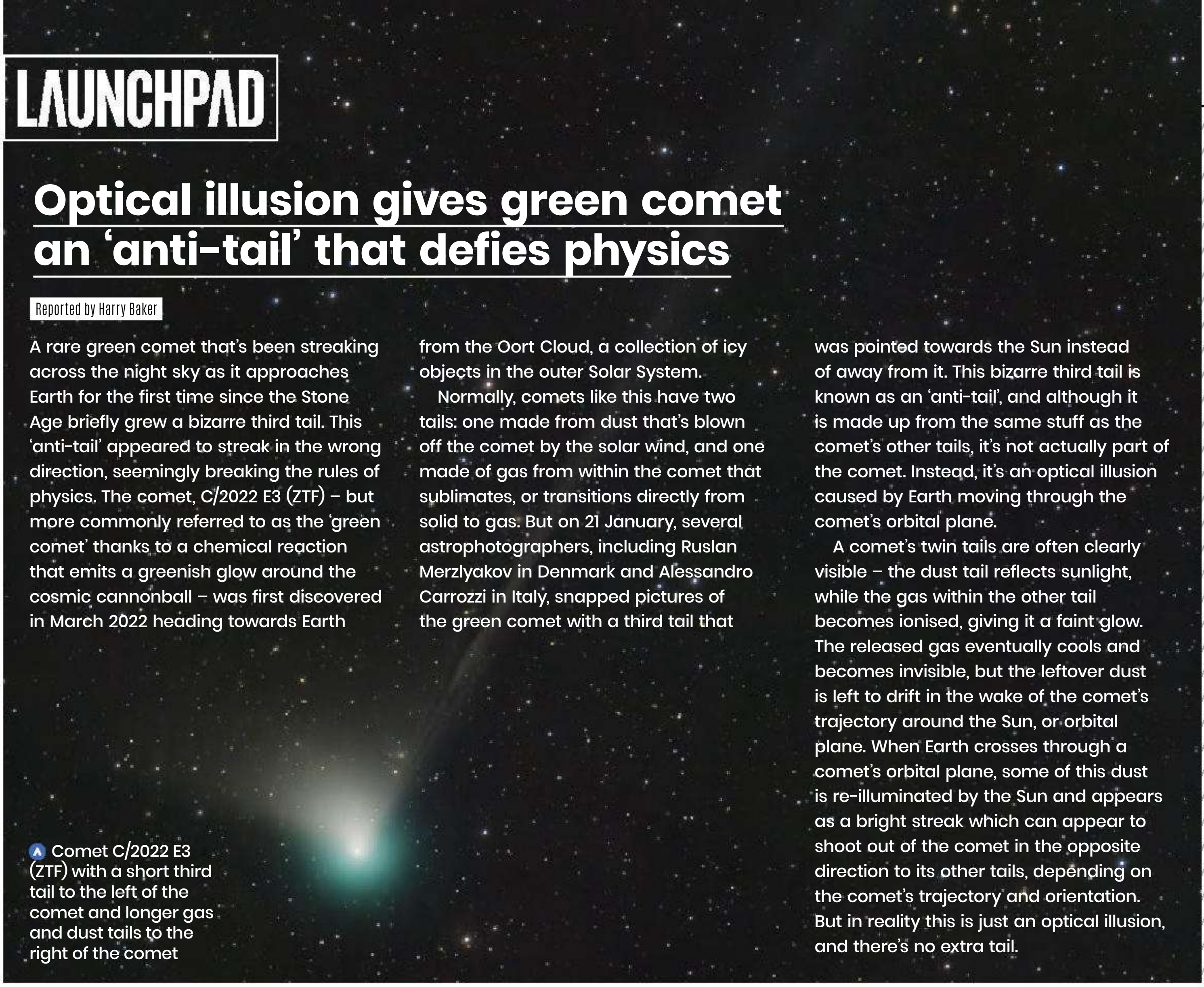
When most people think of Canadian technology in space, they think of flashy projects like Canadarm – the robotic arm series that has served the Space Shuttle, the International Space Station and soon NASA's Gateway lunar station. More astute observers may also cite space medicine or even rocketry as fields in which Canada has expertise. MCSS represents what many small space Canadian companies do: provide essential software or components that fly in the background, fuelling missions all over the world. The company doesn't advertise all of its work. Often MCSS customers want media attention on their own mission, Reid said. "That's why this demonstration with the Canadian Space Agency is nice, because it's very much in the public domain and we're allowed to talk about it," Reid said.

If all goes to plan, Rashid will run for around one lunar day (29 Earth days) on the surface. It's not expected to last the lunar night, but as a demonstration mission that's just fine for MCSS. It has plans to leverage a lot from a few precious days on the Moon. MCSS will receive the Rashid rover's navigation images via the Japanese lander, which will handle communications with Earth. With the Canadian company's algorithm, "every single pixel in the image [will be] classified as a certain terrain type," Reid said. "That output will then be sent to the ground and will be used by scientists and engineers at our office in Ottawa, as well as at other Canadian universities, to help decide where the rover should go," he added. Future missions will take the human 'out of the loop' once engineers are confident the AI knows how to tell different minerals apart and distinguish between critical mission items like rocks and craters.


The United Arab Emirates' Rashid rover will bear Canadian artificial intelligence on the Moon to get ready for future lunar missions

HOW IT WORKS
subscription offer
FROM £2.50 PER ISSUE!
PRINT
£3.83 PER ISSUE
DIGITAL
£2.50 PER ISSUE
PRINT & DIGITAL
£5.08 PER ISSUE
This offer is only available via our online shop
www.magazinesdirect.com

© XXXXXXXXXXXXX



Optical illusion gives green comet an 'anti-tail' that defies physics

Reported by Harry Baker

A rare green comet that's been streaking across the night sky as it approaches Earth for the first time since the Stone Age briefly grew a bizarre third tail. This 'anti-tail' appeared to streak in the wrong direction, seemingly breaking the rules of physics. The comet, C/2022 E3 (ZTF) – but more commonly referred to as the 'green comet' thanks to a chemical reaction that emits a greenish glow around the cosmic cannonball – was first discovered in March 2022 heading towards Earth from the Oort Cloud, a collection of icy objects in the outer Solar System.

Normally, comets like this have two tails: one made from dust that's blown off the comet by the solar wind, and one made of gas from within the comet that sublimates, or transitions directly from solid to gas. But on 21 January, several astrophotographers, including Ruslan Merzlyakov in Denmark and Alessandro Carrozzi in Italy, snapped pictures of the green comet with a third tail that was pointed towards the Sun instead of away from it. This bizarre third tail is known as an 'anti-tail', and although it is made up from the same stuff as the comet's other tails, it's not actually part of the comet. Instead, it's an optical illusion caused by Earth moving through the comet's orbital plane.

A comet's twin tails are often clearly visible – the dust tail reflects sunlight, while the gas within the other tail becomes ionised, giving it a faint glow. The released gas eventually cools and becomes invisible, but the leftover dust is left to drift in the wake of the comet's trajectory around the Sun, or orbital plane. When Earth crosses through a comet's orbital plane, some of this dust is re-illuminated by the Sun and appears as a bright streak which can appear to shoot out of the comet in the opposite direction to its other tails, depending on the comet's trajectory and orientation. But in reality this is just an optical illusion, and there's no extra tail.

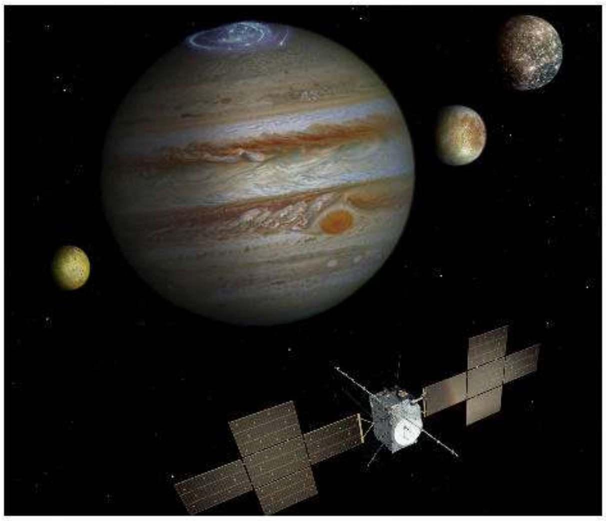
Comet C/2022 E3 (ZTF) with a short third tail to the left of the comet and longer gas and dust tails to the right of the comet

Europe's mission to Jupiter's moons prepares for April launch

Reported by Andrew Jones

Europe's mission to explore three icy moons of Jupiter is all set to begin its voyage to the outer Solar System. The Jupiter Icy Moons Explorer, also known as JUICE, will study Europa, Ganymede and Callisto to provide insights into their nature, evolution, possible subsurface oceans and the potential to harbour life. JUICE has been undergoing final testing at Airbus facilities in Toulouse, France, and will shortly begin its journey to the European Space Agency's (ESA) Guiana Space Centre in French Guiana on South America's Atlantic coast. From there, the 6,200-kilogram spacecraft will launch on one of the last two Ariane 5 rockets. "The launch is currently targeted for 14 April," ESA director general Josef Aschbacher said.

JUICE is scheduled to reach Jupiter in 2031 and will then make a series of flybys of the icy Galilean moons. It will finally enter orbit around Ganymede in 2034 to begin a more detailed nine-month-long study of the moon, which will also be the first time a spacecraft orbits a moon other than our own. JUICE will use its ten cutting-edge science payloads to further our understanding of the moons. One major focus will be the internal subsurface oceans underneath the moons' crusts, which JUICE will target by studying the moons' magnetic fields and looking at their tidal interactions with other worlds in the Jupiter system. "We are not monitoring fish or big fish or creatures in these lakes, but we are seeing how these moons are composed and whether they could be habitable or not," Aschbacher said.



JUICE will look for evidence of subsurface oceans

© ESA; NASA

WIN

SKY-WATCHER SKYHAWK-114

This excellent telescope is the perfect companion for beginners through to seasoned astronomers

TELESCOPE
Sky-Watcher

Included with the Sky-Watcher Skyhawk-114 Newtonian reflector is a 2x Barlow Lens, 10 and 25-millimetre eyepieces, a red-dot finder, an equatorial mount, sturdy aluminium tripod and handy accessory tray for a fully equipped night of observing. The Skyhawk-114 features a primary mirror size of 114 millimetres (4.5 inches) and a focal length of 1,000 millimetres (39 inches), resulting in a focal ratio of f/8.77 that presents excellent views of stars, Solar System targets, star clusters, galaxies and nebulae. The lightweight design and hand-controlled equatorial mount make it easier than ever to track any celestial object as it moves across the night sky. With the longer nights of winter reaching the Northern Hemisphere, the Skyhawk-114 is the perfect companion for exploring a catalogue of stunning celestial sights.

To be in with a chance of winning, answer this question:

Camelopardalis is another name for which constellation?

A: The Giraffe
B: The Camel
C: The Chameleon

Competition ends on 23 March 2023

Enter via email at
space@spaceanswers.com
Visit the website for full terms and conditions at
futureplc.com/terms-conditions

100 WONDERS *of the* UNIVERSE

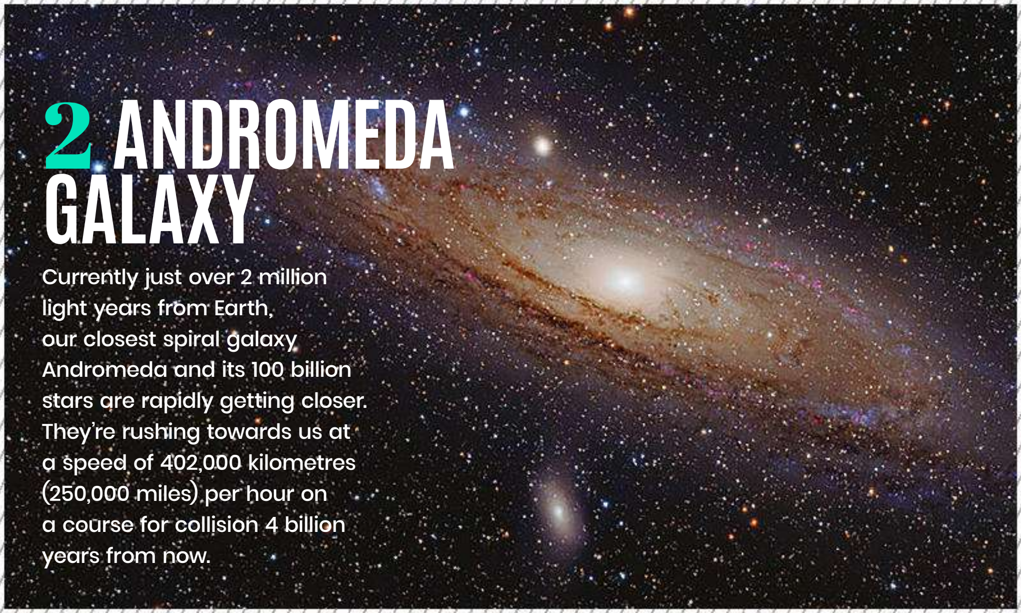
OUR COSMOS IS FULL OF AMAZING SIGHTS, FROM EXOTIC EXOPLANETS TO STUNNING GALAXIES

1

SATURN'S RINGS

First observed by Galileo in 1610, these structures are incredibly thin, just one kilometre (0.62 miles) from top to bottom. They're made up of billions of particles of ice and rock, some as large as mountains and others too small to be seen with the naked eye. It's not known how old the rings are, or how they formed, but it's thought that the fragments are pieces of shattered moons, smashed to bits by collisions in the not too distant past.

© Getty; Alamy; NASA

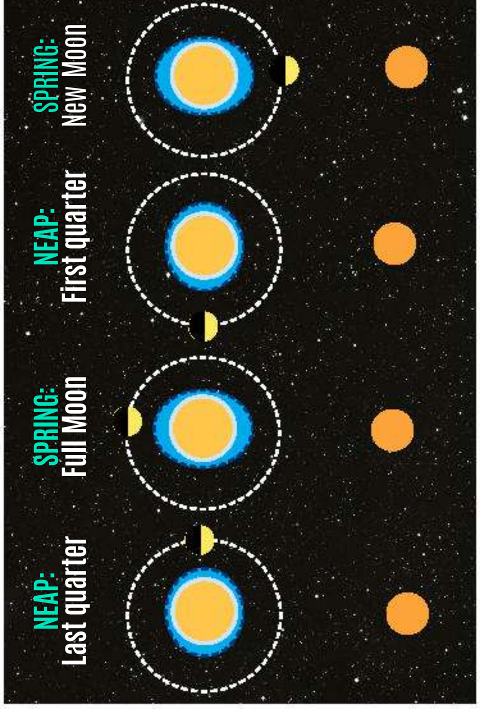


2 ANDROMEDA GALAXY

Currently just over 2 million light years from Earth, our closest spiral galaxy Andromeda and its 100 billion stars are rapidly getting closer. They're rushing towards us at a speed of 402,000 kilometres (250,000 miles) per hour on a course for collision 4 billion years from now.

3 THE MOON

The Moon is a wonder right on our doorstep. As it orbits Earth, its gravity tugs on the oceans, creating a measurable bulge. As the oceans swell, we see the effects as tides. The Sun has a similar, but smaller, effect, and when the Moon and the Sun are in line, the pull on the oceans adds together, creating extra high 'spring tides' once a fortnight.



4 THE PILLARS OF CREATION

These iconic columns of gas and dust were first imaged by the Hubble Space Telescope in 1995, and in 2015 the pictures were retaken in high definition. Lit by ultraviolet radiation released by massive young stars in the Eagle Nebula, the pillars are constantly being shaped, heated and eroded, and hidden inside are the infrared traces of brand-new stars.

5 SOMBRERO GALAXY

Named for its Mexican-hat-like appearance, Messier 104 is a galaxy within a galaxy. The flat disc, viewed almost side-on from Earth, is the most obvious feature, resembling the wide brim of a hat, but if you look again in the infrared spectrum a much larger elliptical galaxy becomes visible, completely encasing the central disc.

6 LIFE

As far as we know, Earth is the only planet to harbour living organisms, but chances are there are many more planets out there like our own.

7 GREAT RED SPOT

Jupiter's Great Red Spot is by far the biggest storm in the Solar System. It's given its red colour by the effects of ultraviolet light on the clouds.

8 THE LEONID METEOR SHOWER

These gleam in November as we pass through a trail of dust and gas left by Comet 55P/Tempel-Tuttle.

9 METHANE SEAS

Weather isn't exclusive to worlds like our own; Saturn's moon Titan has seas, clouds and rain of liquid methane.

10 GIANT CLIFF ON A MOON

The tallest cliff in the Solar System is on Uranus' moon Miranda. Verona Rupes is 20 kilometres (12 miles) deep.

11 ACID ATMOSPHERE

The atmosphere of Venus is 96 per cent carbon dioxide. It has little water, and the clouds are made from corrosive sulphuric acid.

12 ACCRETION DISC

Black holes are surrounded by a spiralling disc of trapped matter. It keeps swirling until something disturbs the disc and it tumbles into the void.

13 VESTA'S GIANT MOUNTAIN

Rheasilvia peak at the centre of Rheasilvia crater on the asteroid Vesta is 22 kilometres (13 miles) high.

14 DARK NEBULAE

These clouds are so dense that no light can pass through; it's all absorbed, making it appear as though there are gaps in space.

15 SHOOTING STARS

These wonders of the night sky fascinate humanity. They happen when chunks of dust and rock burn up as they pass through the atmosphere.

16 STELLAR MAGNETS

Magnetars are neutron stars with intense magnetic fields. They are rare and extremely unpredictable.

17 TITAN

Titan is unique in the Solar System; it's the only satellite with its own atmosphere and is covered in seas of liquid ethane and methane.

18 HOT TEA STAR

Nearby brown dwarf CFBDSIR 1458+10B is part of a binary system and has a surface temperature comparable to a freshly made cup of tea.

19 HYPERVELOCITY STARS

Some stars travel at speeds over 3.2 million kilometres (2 million miles) per hour, fast enough to escape the pull of their parent galaxy.

20 HIMIKO

Also called the Lyman-alpha blob, Himiko is an enormous ancient galaxy; it's so far away that we are looking 800 million years into the past.

21 HAMBURGER GALAXY

Positioned edge-on to Earth, this spiral galaxy appears to us like a flat red-orange disc of stars and dark dust.

22 RED SQUARE NEBULA

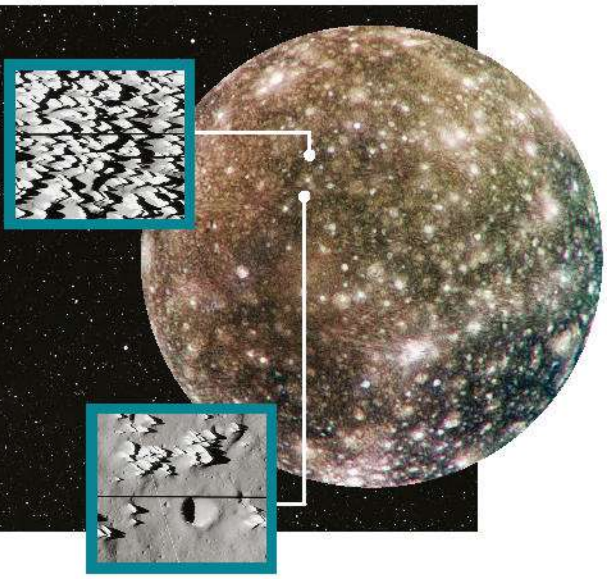
The unusual geometric shape of this nebula, found in the constellation of Serpens, remains a mystery. The leading hypothesis is that we're looking at the side of several cones of gas released by the star or stars sitting at the centre. The cones are at right angles to one another, producing a square, but if we looked from a different angle we would be able to see directly into one of the cones, and it would appear as a red ring.

23 THE DIAMOND RING

This photograph by the European Southern Observatory's Very Large Telescope might look like a single object in the form of a cosmic diamond ring, but it's the result of an interaction between two objects. The ring itself is formed by the bubble of a planetary nebula known as Abell 33, created when the atmosphere of a dying Sun-sized star ballooned into space. The 'diamond' is a well-positioned bright foreground star.

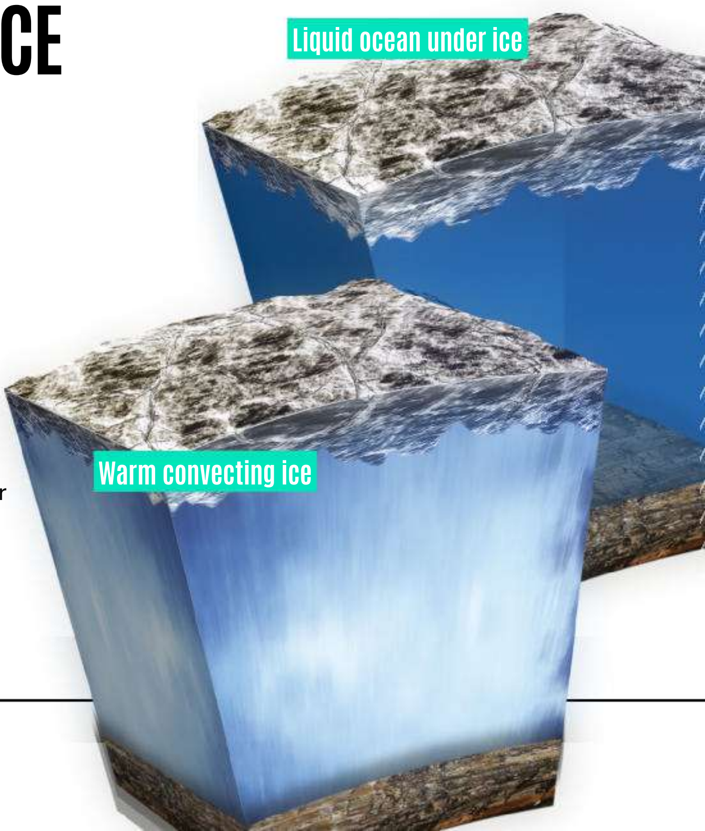
24 CALLISTO ICE SPIRES

Jupiter's moon Callisto was thought to be a dead object, an ancient cratered world coated in a layer of ice, but images captured by NASA's Galileo spacecraft in 2001 revealed spires jutting out from the surface. The icy spikes are coated in dark dust which absorbs heat from the Sun, causing the ice to melt and gradually eroding the surface.



25 SUBSURFACE OCEANS

Beneath the surfaces of seemingly frozen moons there are potentially vast quantities of liquid water. In the far reaches of the Solar System the temperature plummets, but friction caused by the gravitational interactions between a moon and its parent planet could melt subsurface ice, resulting in hidden oceans. The tidal motion of these oceans as the moon orbits would help keep the water in liquid form. The best candidates for subsurface water in the Solar System are Jupiter's moons Europa, Callisto and Ganymede, and Saturn's moons Mimas and Enceladus.



26 VALLES MARINERIS

Valles Marineris is Mars' answer to the Grand Canyon, but on a grander scale. It extends for 3,000 kilometres (1,800 miles) and cuts an eight-kilometre (five-mile) deep scar into the planet's surface.

27 HELLAS PLANITIA

Hellas Planitia is an ancient impact crater over 2,000 kilometres (1,200 miles) in diameter. This enormous scar on the southern hemisphere is the largest complete crater on the surface of Mars.

28 OLYMPUS MONS

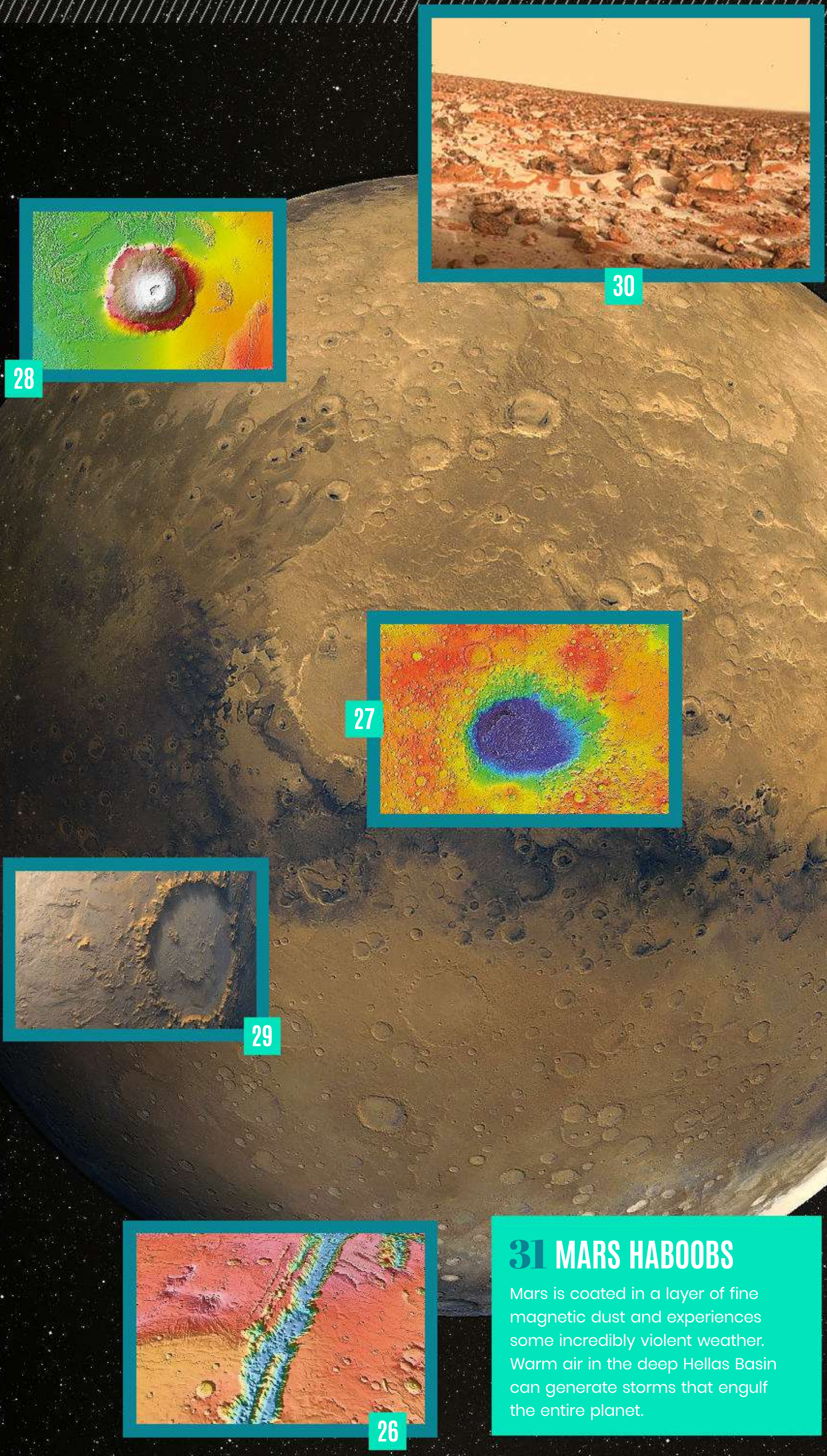
This imposing mountain is the tallest volcano in the Solar System, standing at an incredible 25 kilometres (16 miles) tall. It easily eclipses the tallest volcano on Earth, Mauna Loa in Hawaii.

29 FACES ON MARS

Viking 1 was greeted by a strangely familiar sight upon landing: two faces were staring back from the bare rocks on the surface. High-resolution images of these features revealed both to be natural landforms.

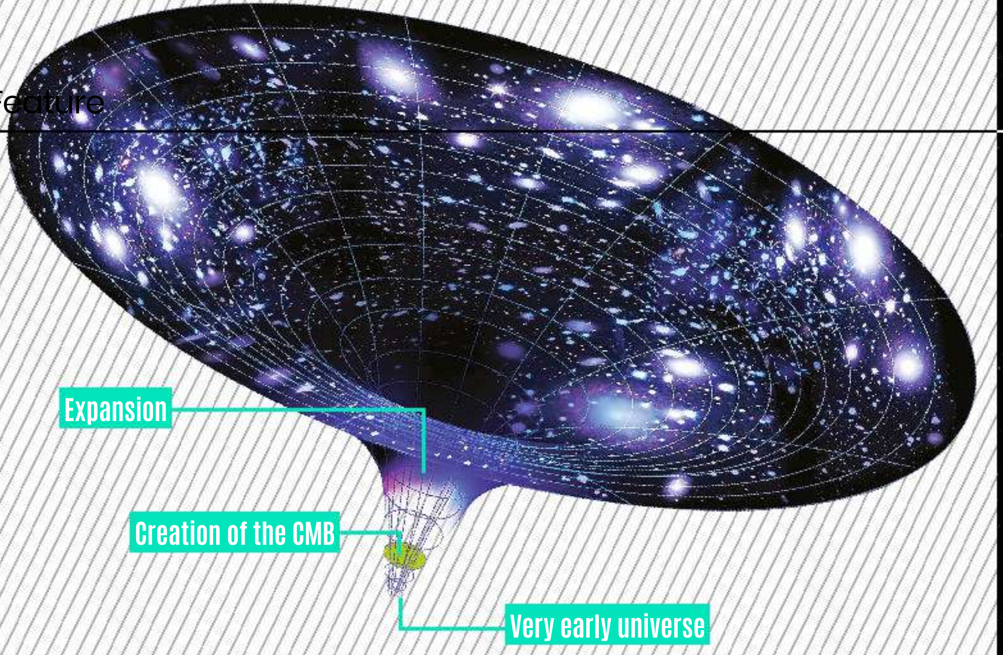
30 UTOPIA PLANITIA

The crater of this impact basin contains landforms known as 'thermokarst', with geometrically shaped lines and depressions with scalloped edges. When Viking 2 arrived in 1979, it found a thin layer of ice on the surface.



31 MARS HABOOBS

Mars is coated in a layer of fine magnetic dust and experiences some incredibly violent weather. Warm air in the deep Hellas Basin can generate storms that engulf the entire planet.



32 COSMIC MICROWAVE BACKGROUND

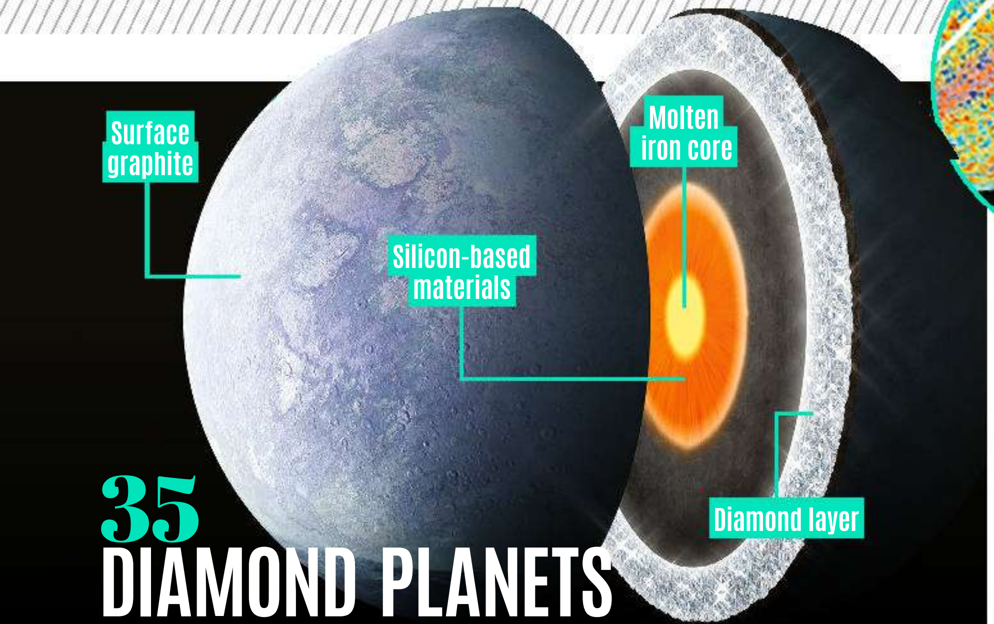
The cosmic microwave background (CMB) is evidence of the Big Bang written all over the fabric of the universe. It was discovered by Bell Telephone Laboratories in the 1960s and was originally little more than a nuisance, interfering with radio communications. It soon became clear that this background radiation was special. The CMB represents the oldest light in the universe – the thermal radiation left over from the Big Bang. The early universe was hot and dense, but over the last 13.8 billion years it has stretched and cooled. As the universe has expanded, the heat signature expanded with it, leaving behind a visible fingerprint in the form of a uniform layer of microwave radiation.

33 MASSIVE WATER RESERVOIR

The quasar APM 08279+5255 hides a black hole 20 billion times the Sun's mass and contains an ancient water cloud. The gas surrounding the black hole contains 140 trillion times more water than Earth's oceans.

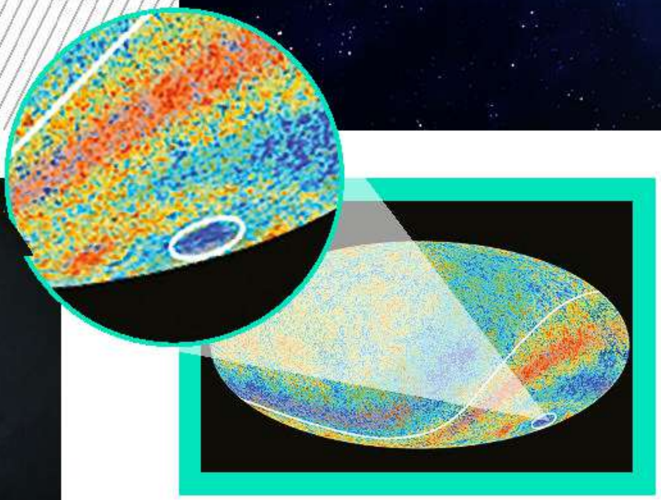
34 GAMMA-RAY BURSTS

About once a day, a random point in the sky blazes with an intense pop of energy known as a gamma-ray burst. Some bursts are thought to be the final firework display of a massive star as it collapses down to form a black hole.



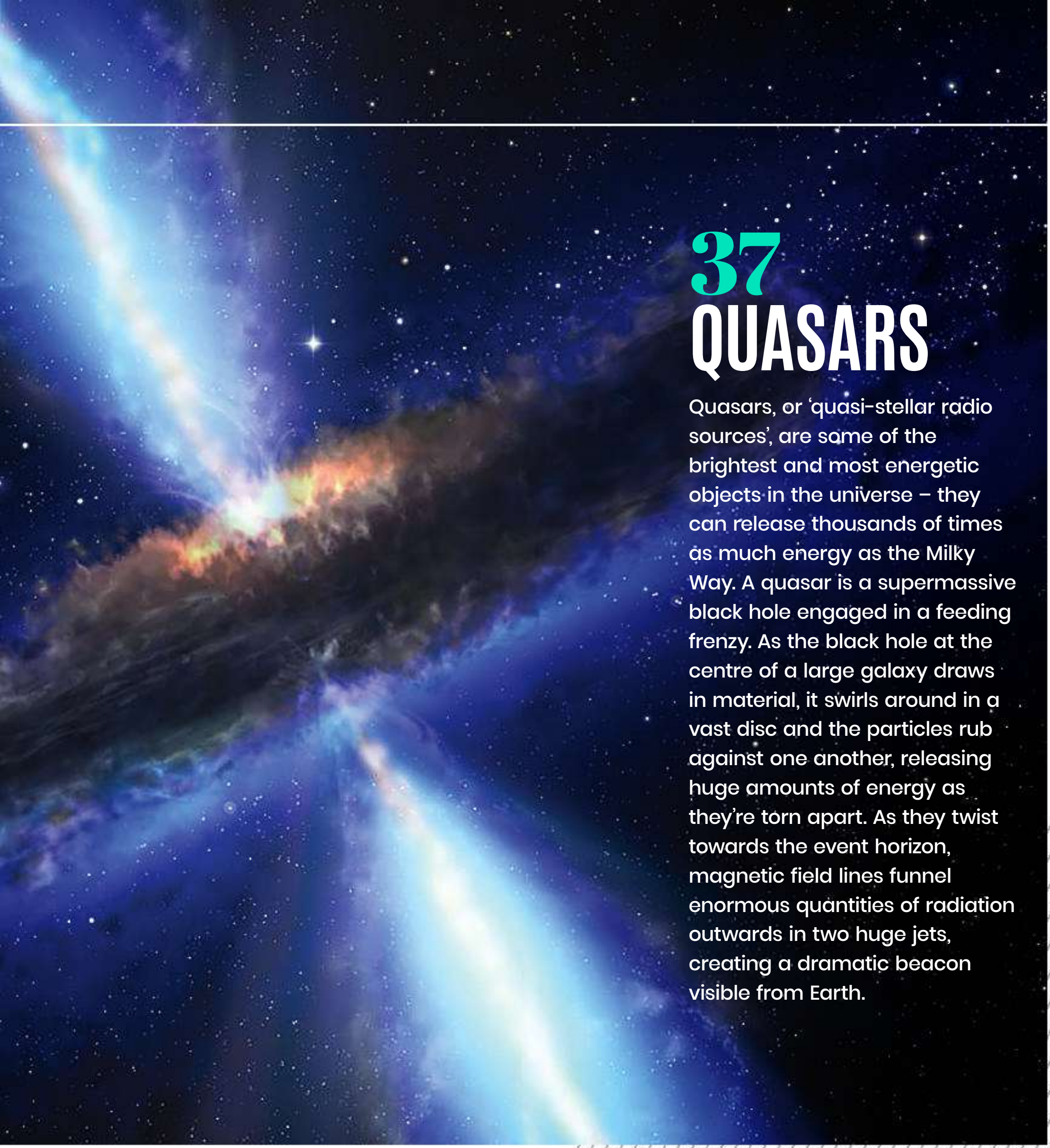
35 DIAMOND PLANETS

Our Solar System is dominated by oxygen, and the terrestrial planets inside it are made from silicon-based rocks. But elsewhere in the universe it's a different story. In carbon-dominated systems, some planets are thought to be made from diamond. One of the first candidates for a diamond planet is a super-Earth known as 55 Cancri e. It's 40,000 light years away, twice the size of Earth and almost eight times the mass, and beneath a surface of graphite, planetary scientists think it could contain a thick shell of precious stones and other crystal structures.



36 THE CMB COLD SPOT

The cosmic microwave background is the afterglow of the Big Bang, and is relatively uniform across the entire sky. However, there's a strange cold spot in the lower right-hand corner. The chance of this happening at random is around 1 in 100, and its presence is puzzling cosmologists. Possible explanations put forward include an enormous supervoid, a defect known as 'texture' and even the presence of a parallel universe.

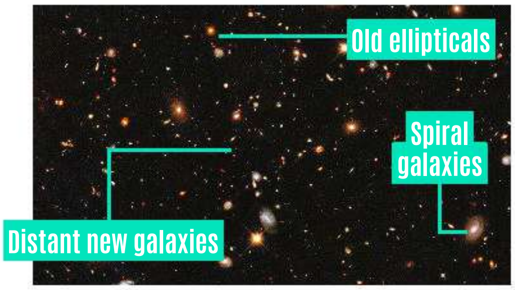


37
QUASARS

Quasars, or 'quasi-stellar radio sources', are some of the brightest and most energetic objects in the universe – they can release thousands of times as much energy as the Milky Way. A quasar is a supermassive black hole engaged in a feeding frenzy. As the black hole at the centre of a large galaxy draws in material, it swirls around in a vast disc and the particles rub against one another, releasing huge amounts of energy as they're torn apart. As they twist towards the event horizon, magnetic field lines funnel enormous quantities of radiation outwards in two huge jets, creating a dramatic beacon visible from Earth.

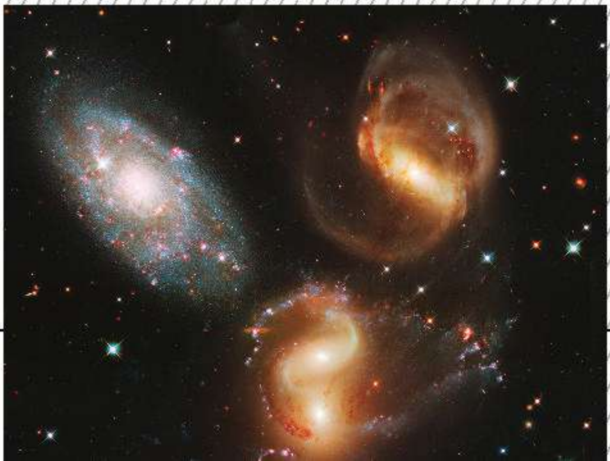
38 HUBBLE DEEP FIELD

One of the most astonishing things about space is what appears when you point a telescope at 'nothing'. Between 2003 and 2004, Hubble was aimed at a portion of sky in the constellation of Fornax. In the eight years that followed, it kept returning, creating an even more detailed image of what appeared to be a blank patch of sky. The images revealed a sea of galaxies stretching back in space and time 13.2 billion light years, almost to the birth of the universe.



39 STEPHAN'S QUINTET

This cluster of five galaxies was discovered in the 19th century and demonstrates the effects of gravity on a monumental scale. Three of the galaxies are so close that immense gravitational tides have made visible changes to their structures, pulling on their spiral arms and distorting their shapes as they twist towards an inevitable collision. The bluer galaxy at the bottom left is an interloper, 240,000 light years away from the others and is not actually part of the group.



40 DARK ENERGY

The mysterious dark energy is accelerating the expansion which followed the Big Bang. It is thought to make up around 68 per cent of the universe.

41 DARK MATTER

27 per cent of the universe is thought to be composed of dark matter, made up of particles that interact only weakly with 'ordinary' matter.

42 RARE TYPES OF MATTER

'Normal' matter, made up of protons and neutrons makes up just five per cent of the universe. The rest is dark matter and dark energy, both still directly undetected.

43 RED DWARFS

These small, dim stars burn so slowly that they're thought to have life spans longer than the total age of the universe, meaning that none are yet old enough to have died.

44 ASTEROID BELT

Between Mars and Jupiter lies a band of leftovers from the start of the Solar System – the remnants of a planet that failed to form or the fragments of a broken one.

45 OORT CLOUD

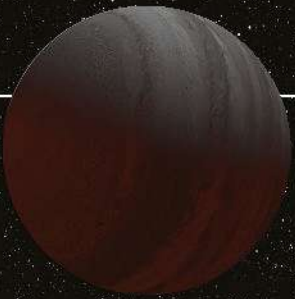
The Solar System is encased in a sphere of icy objects, collectively known as the Oort Cloud. The Sun's gravity at that distance is so weak that passing objects can send comets hurtling inwards.

46 BACKWARDS SPIRAL GALAXY

The arms of spiral galaxies trail backwards as they turn, but NGC 4622 is turning in the same direction that its arms point, possibly as the result of a collision that upset its spin.

47 EXOPLANETS

Until 1992, the planets of the Solar System were the only planets that we were aware of in the universe, but it was always thought likely that other stars had companions. The first exoplanet was found orbiting a pulsar. Just a few years later, another was discovered orbiting a Sun-like star. Currently, we've confirmed 5,297 exoplanets.

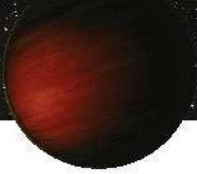


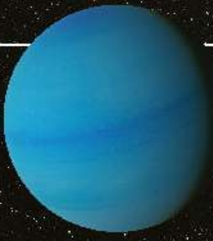
Hot Jupiter HD 189733 b

These enormous gas giants orbit close to their parent stars. Some, like HD 189733 b, orbit closer than Mercury.

Chthonian planet HD 209458 b

Chthonian planets are the hypothetical rocky remnants left behind after a close orbit evaporates a gas giant's gas.



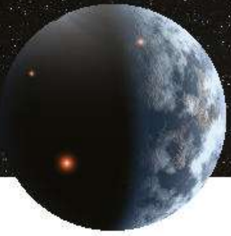


Hot Neptune Gliese 436 b

These Neptune-sized planets orbit close to their parent stars, and so a year on the surface passes by quickly.

Water world Kepler-22b

Some are thought to support liquid water on the surface, but others are hot, steamy and unstable.



48 SUPERNOVAE

When massive stars die they go out with a bang, releasing as much energy as the Sun will during its entire lifetime in just fractions of a second.

49 SOUTH POLE-AITKEN BASIN

The south pole of the Moon has a spectacular impact crater that's around 2,600 kilometres (1,600 miles) in diameter.

50 CHELYABINSK METEORITE

This 19-metre (62-foot) wide asteroid exploded in mid-air over Russia in 2013, an event that happens on this scale around once every 30 years.

51 CATACLYSMIC VARIABLE STARS

In some binary systems, a white dwarf and a larger star orbit close to one another. The white dwarf feeds on its companion, creating an accretion disc that glows.

52 TOTAL SOLAR ECLIPSE

Only possible thanks to the chance position of the Moon, at its current distance the Moon appears the perfect size in the sky to cover the Sun's disc as they line up.

53 HORSEHEAD NEBULA

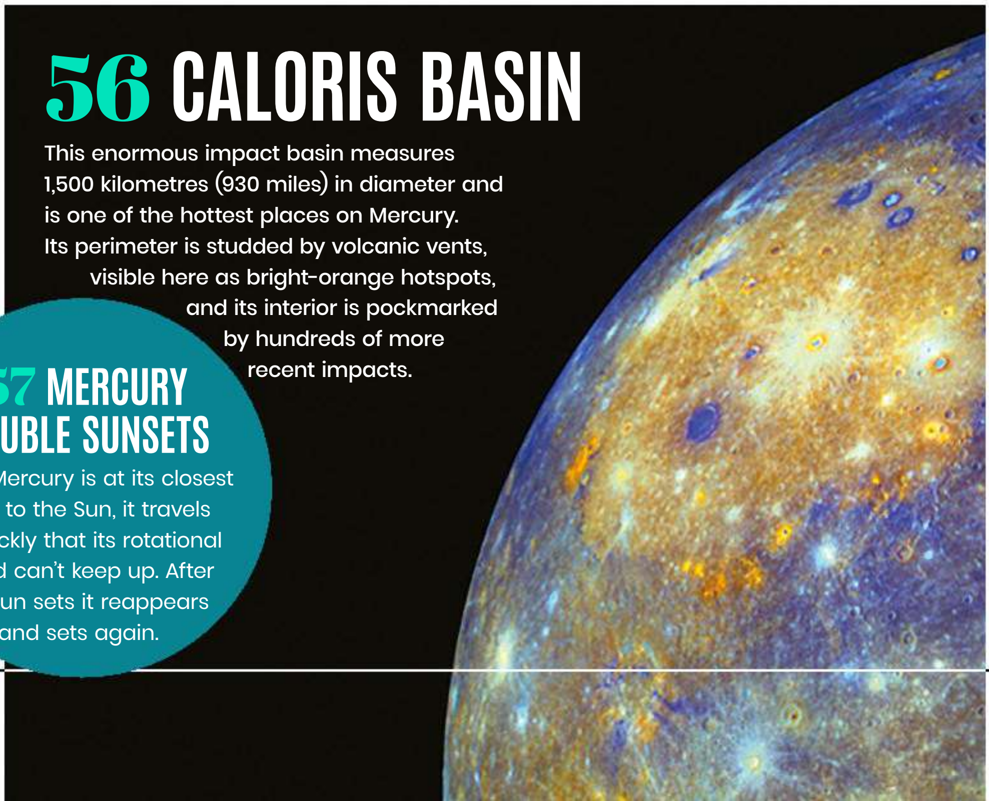
This remarkable pillar of dense dust and gas is named after the horse-like head and neck at its tip. It's part of a larger optical nebula known as Barnard 33 and is visible in pink silhouette thanks to an extremely bright five-star system, Sigma Orionis – part of the constellation of Orion.

54 EINSTEIN CROSS

The universe is made from a fabric called space-time, and mass causes this fabric to bend. This Einstein Cross is a single quasar, but it looks like four because a galaxy sitting in front of it bends space-time, curving the light as it passes and acting like a lens to duplicate the image.

55 AURORAE ABOVE EARTH

The Sun releases a stream of charged particles called the solar wind, and this feeds into the magnetosphere around our planet, dislodging other particles and slamming into the gases that make up the atmosphere. These collisions excite the gas molecules and make them glow.



56 CALORIS BASIN

This enormous impact basin measures 1,500 kilometres (930 miles) in diameter and is one of the hottest places on Mercury. Its perimeter is studded by volcanic vents, visible here as bright-orange hotspots, and its interior is pockmarked by hundreds of more recent impacts.

57 MERCURY DOUBLE SUNSETS

When Mercury is at its closest point to the Sun, it travels so quickly that its rotational speed can't keep up. After the Sun sets it reappears and sets again.

Super-Earth HIP 116454 b

These planets have a mass greater than Earth, but lower than Neptune. But not all super-Earths are Earth-like.

Gas giant Gliese 504 b

These planets are several times the mass of Earth and are made mostly of gas, with a molten rocky or metallic core.

Terrestrial 55 Cancri e

Made of rock and metal, there could be as many as 40 billion habitable terrestrial planets in the Milky Way alone.

Brown dwarf Teide 1

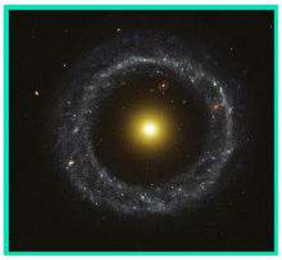
These are larger than planets, but smaller than stars. They are sometimes referred to as 'failed stars'.

Rogue planet WISE 0855-0714

Rogue planets don't orbit a parent star. They orbit the centre of their galaxy, still warmed by their molten core.

58 HOAG'S OBJECT

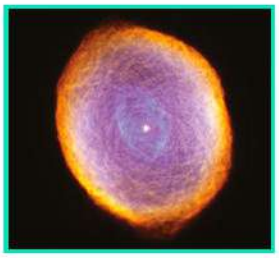
This unusual object is a ring galaxy, one of the rarest galaxy types. At the centre is a spherical bulge of old orange-red stars and around the edges is a ring of bright-blue, hot young stars. Other ring galaxies are thought to have formed following a collision or due to a rapidly spinning central bar, but the origin of Hoag's Object is unknown. If you look inside, another ring galaxy is visible in the distance.



59

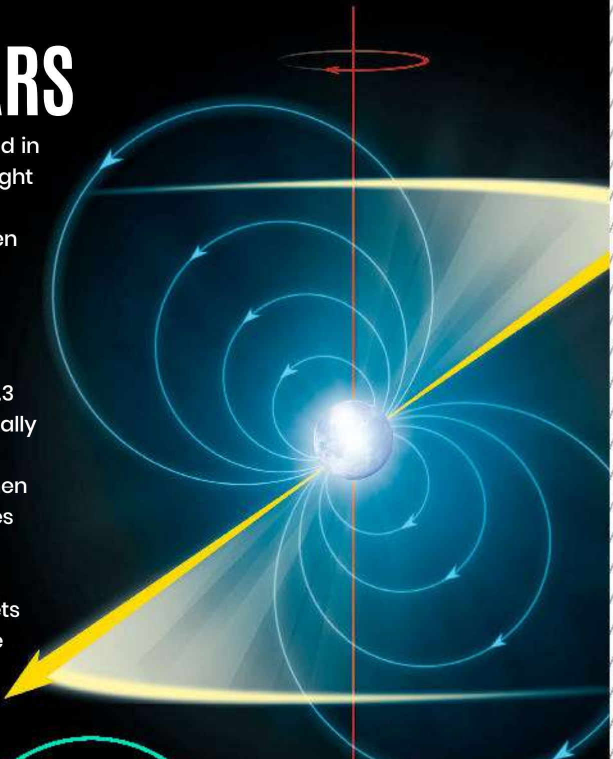
SPIROGRAPH NEBULA

The star at the centre of these geometric swirls used to be like our Sun, but a few thousand years ago it started running out of fuel and ballooned to become a red dwarf. Since then, its fuel has disappeared and its envelope has begun expanding. The white dwarf forming at the centre is unpredictable, and scientists believe that its erratic winds could be making these strange patterns in its nebula.



60 PULSARS

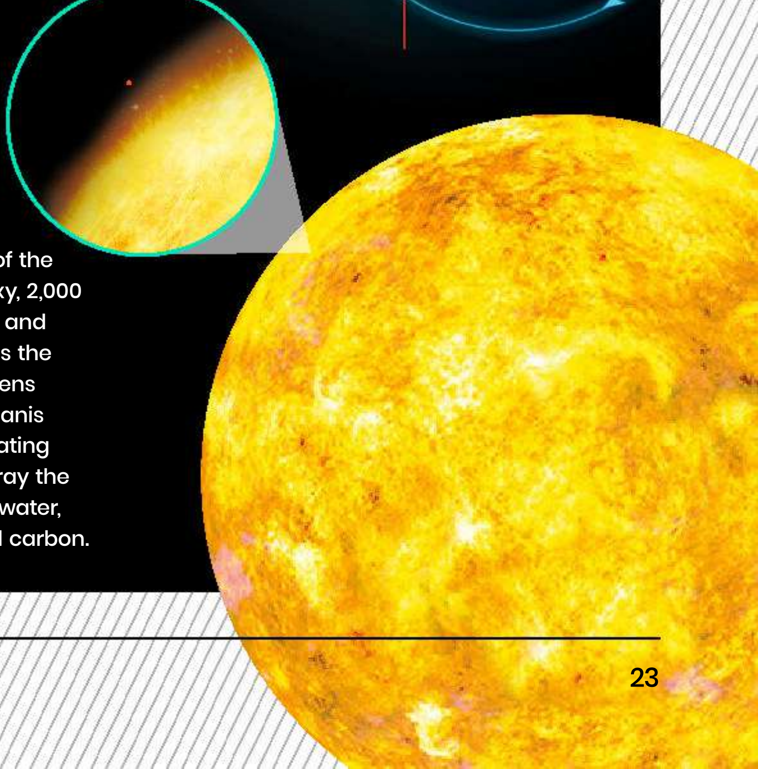
When pulsars were discovered in 1967, Jocelyn Bell Burnell thought she might have intercepted communications from an alien civilisation. While searching for the high-energy twinkling of quasars, she noticed a patch of sky emitting regular pulses of radio waves every 1.3 seconds. The signal was actually generated by a neutron star. Neutron stars are created when a star between 8 and 25 times the mass of the Sun runs out of fuel and collapses. As the neutron star spins, its radio jets spin too, sweeping across the sky in regular pulses.

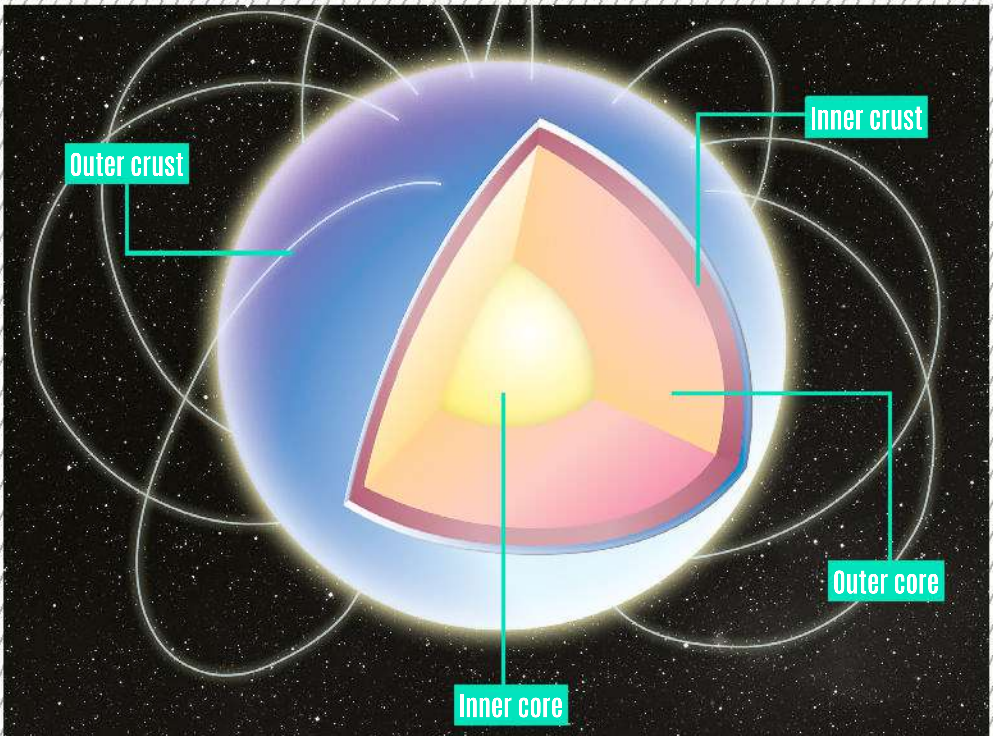


61

MASSIVE STAR

VY Canis Majoris is one of the largest stars in our galaxy, 2,000 times the size of the Sun and between 30 and 40 times the mass. Within just a few tens of millions of years, VY Canis Majoris will collapse, creating a supernova that will spray the surrounding space with water, silicone compounds and carbon.



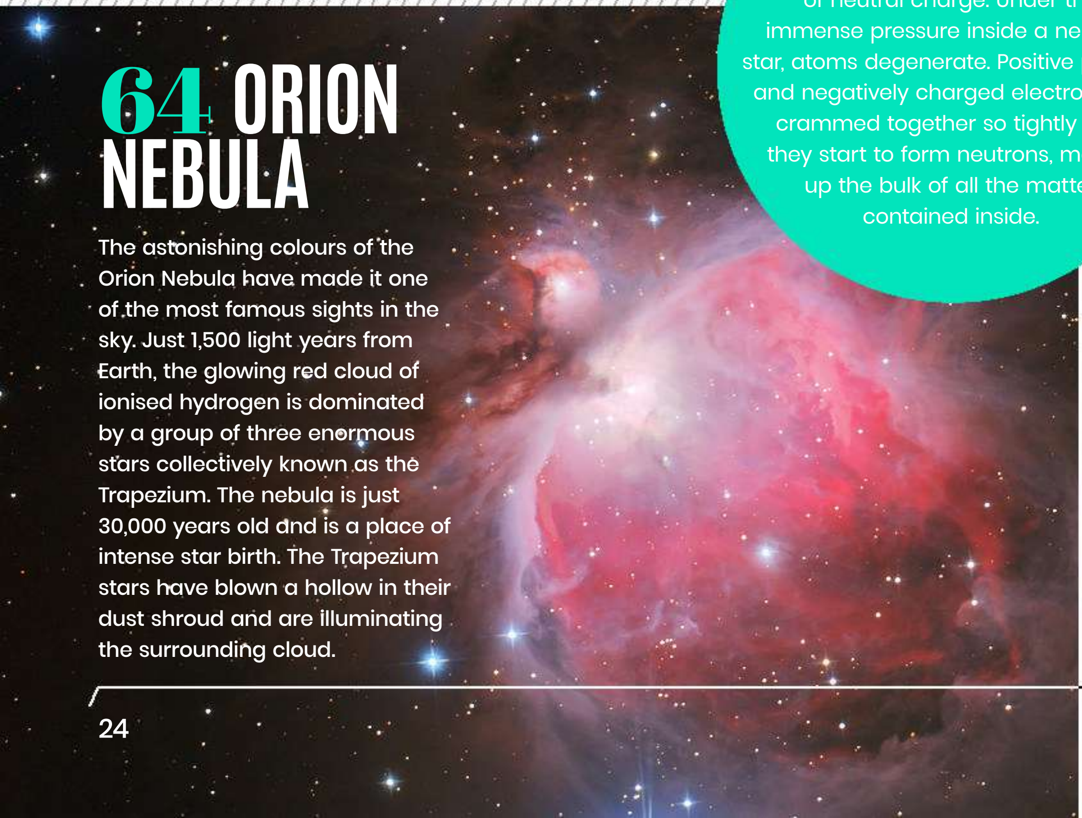


62 NEUTRON STARS

When a massive star runs out of fuel, the outwards explosive force that opposes the inwards crunch of gravity is removed, and in just fractions of a second, the structure collapses. Very large stars collapse entirely to form black holes, but smaller stars still retain a shred of their former presence in the shape of a neutron star. They are the size of a city but contain the mass of around 500,000 Earths. They're so dense that a single teaspoonful of their matter would weigh ten million tonnes.

63 NEUTRONS

Neutrons are subatomic particles of neutral charge. Under the immense pressure inside a neutron star, atoms degenerate. Positive protons and negatively charged electrons are crammed together so tightly that they start to form neutrons, making up the bulk of all the matter contained inside.



64 ORION NEBULA

The astonishing colours of the Orion Nebula have made it one of the most famous sights in the sky. Just 1,500 light years from Earth, the glowing red cloud of ionised hydrogen is dominated by a group of three enormous stars collectively known as the Trapezium. The nebula is just 30,000 years old and is a place of intense star birth. The Trapezium stars have blown a hollow in their dust shroud and are illuminating the surrounding cloud.

65 ANT NEBULA

Between the two segments, a star not unlike our Sun is in the midst of collapse. The shape of its explosion has puzzled astronomers, and rather than being uniform in all directions, the gas is wound up into two symmetrical lobes. It's thought that there may be another star stirring the gas with its gravitational pull or that the spin of the dying star could be creating these enormous swirls in space.

66 TWIN STARS

Around 85 per cent of the stars in the Milky Way are thought to move in pairs, threes or larger groups. They are known as binary or multiple star systems, and instead of existing alone, the companions orbit around a common centre of mass. Some pairs can easily be seen through a telescope, while others look like one bright star, but can be distinguished by fluctuations in the colour of their light as they orbit.

67 CRAB NEBULA

This nebula is the remnant of a supernova explosion that lit up the sky in 1054 CE. The gas cloud is expanding at a rate of around 1,800 kilometres (1,100 miles) per second, and the gas creates a glowing rainbow. In the interior, the blue and green filaments are oxygen and sulphur, and towards the edges, the orange and red are hydrogen and oxygen.

68 WHIRLPOOL GALAXY

This near-perfect swirl is a classic example of a spiral galaxy. Like our own galaxy, bright-blue stars are formed within the enormous arms, twisting around a central bulge of older orange-red stars in the last phases of their existence. The spirals are lined with dust lanes composed of dark silicon and carbon, and clouds of hydrogen gas glow red as they are excited by the light from the young stars.

69 SPACE VOLCANOES

The Solar System is full of volcanic activity. The largest known volcano, Olympus Mons, is located on Mars, and Venus boasts the highest number of volcanoes of any planet, with over 1,600 major volcanic features and tens of thousands of smaller volcanoes. Though neither planet has seen recent volcanic activity, it's possible that some are still active. And volcanoes aren't just restricted to planets; Jupiter's moon Io is more volcanically active than Earth, and Neptune's moon Triton and Saturn's moon Enceladus both harbour cryovolcanoes, which spew not lava but water.

70 IO

Io is the most volcanically active place in the Solar System, capable of jettisoning lava 300 kilometres (190 miles) into the sky. Its atmosphere is thin and sulphurous, and its surface is constantly being smoothed and remodelled by lava flows. Incredibly, Io acts as a lightning rod – as it dips through Jupiter's magnetic field it generates currents of up to 3 million amperes that zip down towards the surface of the gas giant below.

71 LIGHT 'ECHOES'

In 2002, V838 Monocerotis suddenly became incredibly bright and then rapidly dimmed again. During the event, known as a 'light echo', the star grew hugely in diameter, but unlike other ageing stars, it didn't lose its outer layers. Instead they cooled until its surface was almost cold enough to touch. The light emitted was reflected by dust that the star had already expelled, revealing layers of previously invisible swirls.

72 GLOBULAR CLUSTERS

These dense spheres contain ancient red-orange stars and are the oldest subsystems inside galaxies, thought to have formed around 13 billion years ago.

73 REFLECTION NEBULAE

These nebulae don't emit any light of their own, but they reflect light from nearby stars, revealing their dusty outlines.

74 ASTEROID MOONS

It's not just planets that have satellites – around 16 per cent of large near-Earth asteroids have one or two moons of their own.

75 COSMIC VOIDS

The structure of the universe looks something like a three-dimensional web, with most of the galaxies arranged into clumps and filaments. In between, there are vast holes.

76 WOLF-RAYET

These hot, massive stars are nearing the ends of their lives and have started losing their atmospheres at an astonishing rate as solar winds blow their gases into space.

77 CERES

Ceres is the largest object in the asteroid belt. Its growth was stunted by the gravity of Jupiter. At only 950 kilometres (590 miles) across, it's known as an embryonic planet.

78 LARGE QUASAR GROUP

The largest structure in the known universe is a cluster of quasars, the violent nuclei of early galaxies, stretching in a chain that covers 4 billion light years.

79 TINY HOLES

Hypothetical black holes from early in the history of the universe – the mass of a mountain crammed into the volume of just one atom.

80 NEUTRINOS

These subatomic particles are made in violent explosions, but with no mass and no charge they can travel through objects.

81 HOT ICE PLANETS

Temperatures on Gliese 436 b are well above boiling, but the pressure has formed an exotic form of ice.

82 DUNE FIELDS

Earth, Venus, Mars and Titan all share a common feature: wind in the atmosphere of each has swept the surface dust into rippling dunes.

83 HOLE IN SPACE

We're located inside a hole in the interstellar medium known as the Local Bubble, formed by a group of exploding supernovae around 10 million years ago.

84 POLE STARS

Polaris is the current North Star and is almost lined up with magnetic north, but as Earth's axis spins in a cone shape every 26,000 years, this won't always be the case.

85 RUM CLOUD

Sagittarius B2, a cloud near the centre of the Milky Way, contains alcohol, along with a molecule called ethyl formate that smells like rum.

86 DINOSAUR KILLER'S CRATER

Chicxulub is a 66-million-year-old impact crater in Yucatan, Mexico. It's the site of the impact that led to the mass extinction event that killed the dinosaurs.

87 CIGAR GALAXY

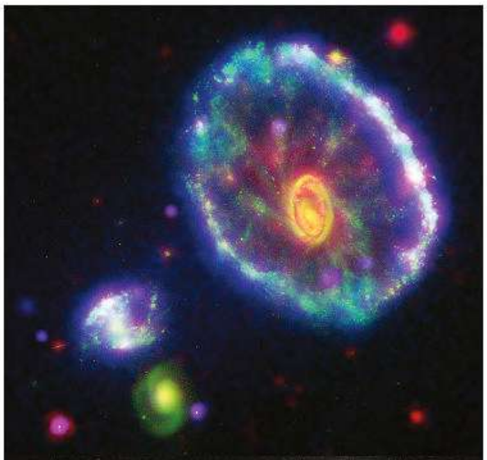
This edge-on spiral is known as a starburst galaxy – a hive of star formation. The new stars are fuelled by supernovae, and several have been observed over the last few decades. The most recent in the area occurred in 2014.

88 HEART NEBULA

A favourite object on Valentine's Day, IC 1805 bears more than a passing resemblance to a heart. The clouds of dust and gas have been shaped by a cluster of newly formed stars known as Melotte 15, only 1.5 million years old.

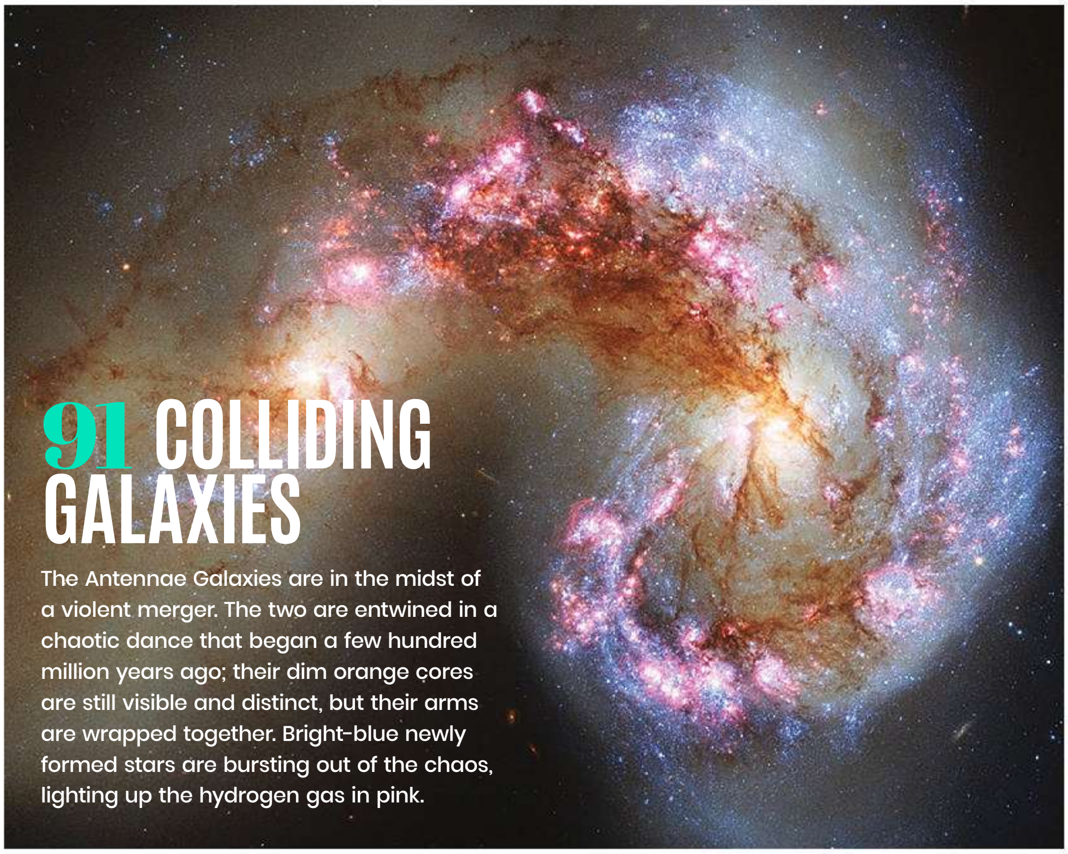
89 TARANTULA NEBULA

Its wispy arms are made from partially ionised hydrogen gas, excited by a supercluster of massive stars. It's the largest star-forming region in nearby space.



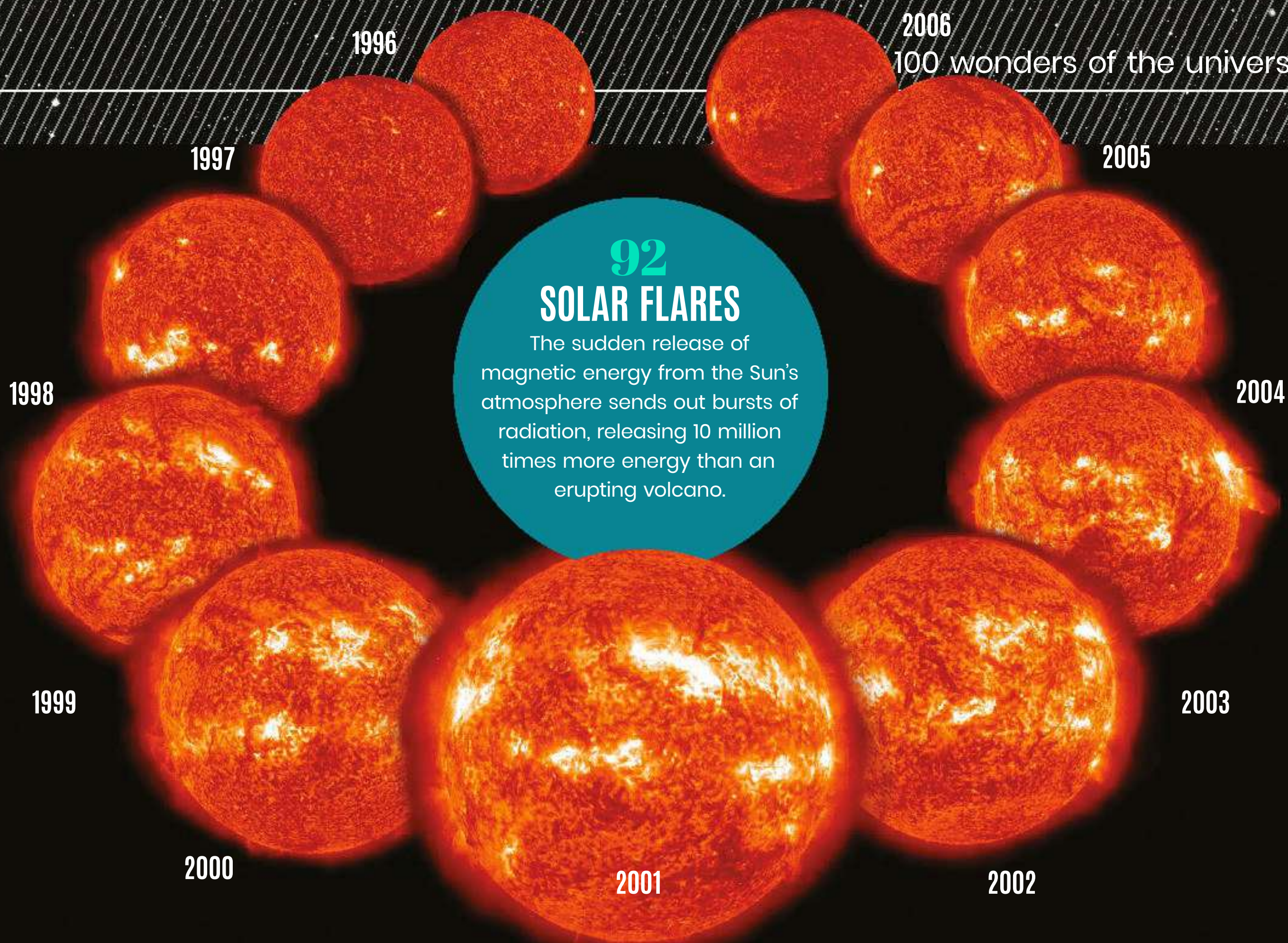
90 CARTWHEEL GALAXY

This spiral suffered a head-on collision that created rings of star formation that rippled out from the centre. Ultraviolet and X-ray light released by new stars and violent black holes are visible as purple and blue, while the green visible light shows the spokes of the cartwheel, revealing clues about the galaxy's shape before the impact.



91 COLLIDING GALAXIES

The Antennae Galaxies are in the midst of a violent merger. The two are entwined in a chaotic dance that began a few hundred million years ago; their dim orange cores are still visible and distinct, but their arms are wrapped together. Bright-blue newly formed stars are bursting out of the chaos, lighting up the hydrogen gas in pink.


1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

92
SOLAR FLARES

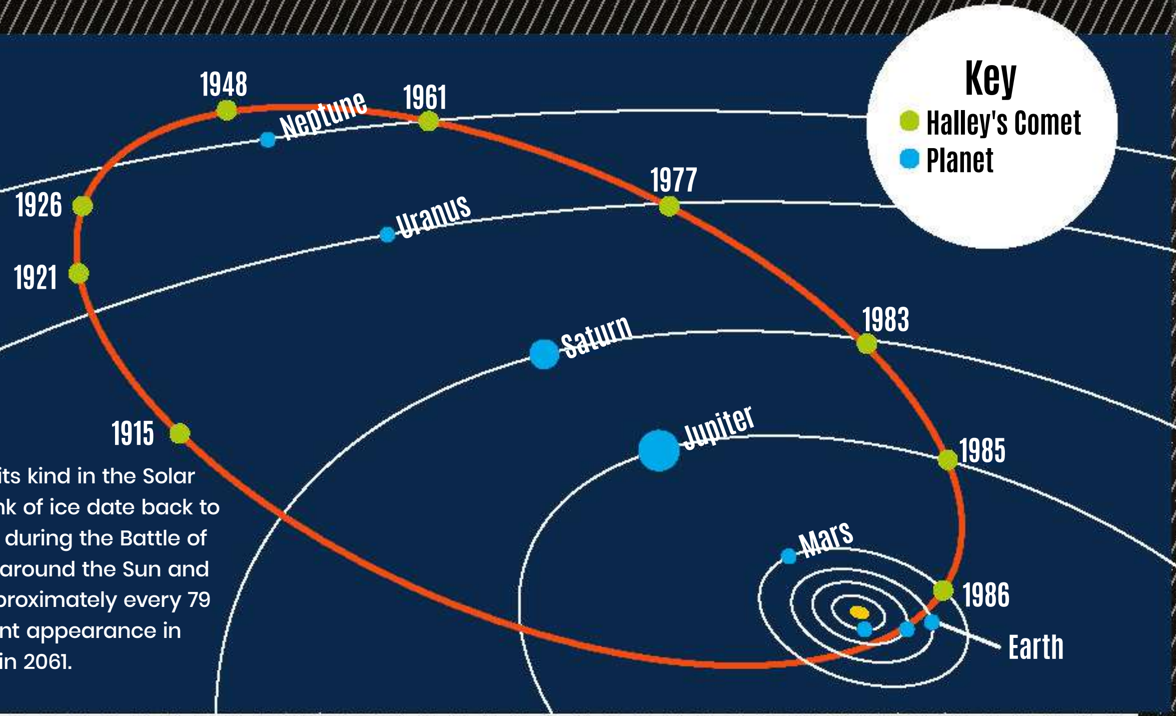
The sudden release of magnetic energy from the Sun's atmosphere sends out bursts of radiation, releasing 10 million times more energy than an erupting volcano.

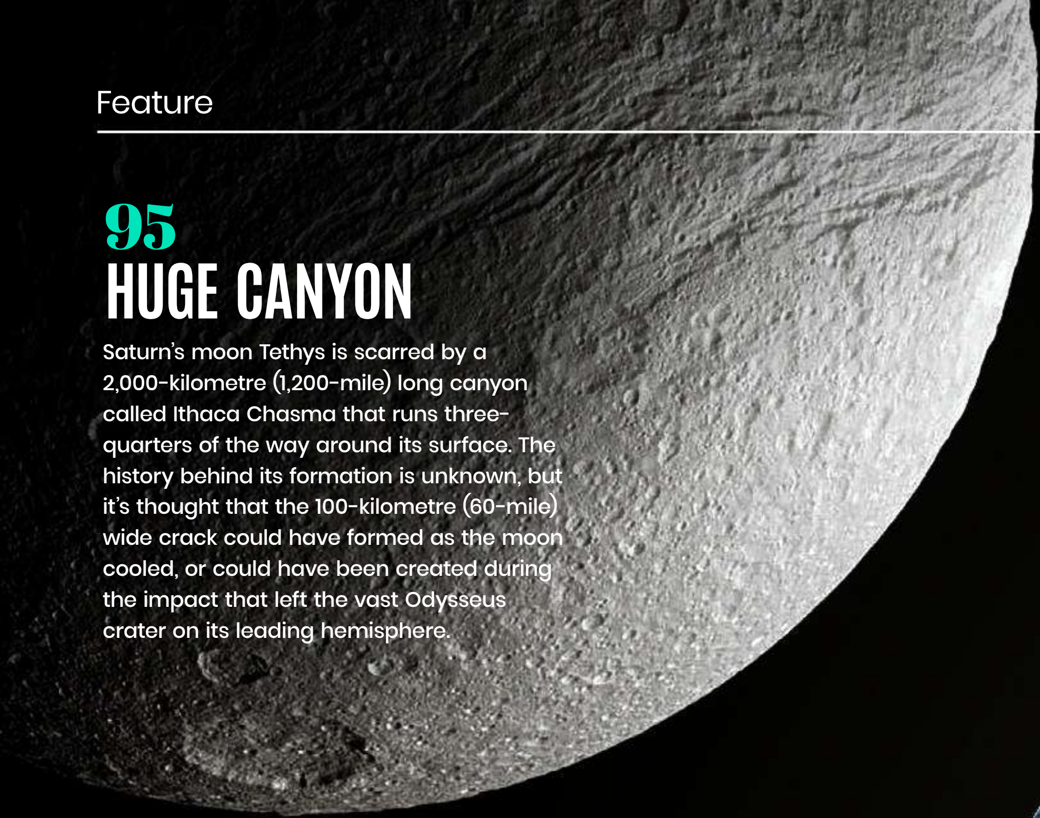
93 SOLAR MAXIMUM

The Sun is a consistent presence in Earth's sky, but it isn't quite as constant as it might appear. Its magnetic flux varies on an approximately 11-year cycle, and at its peak, known as the solar maximum, sunspots are visible on its surface almost continuously. In areas where the Sun's magnetic field is at its strongest, the temperature plummets. This creates visible dark spots, some of which can measure 50,000 kilometres (31,000 miles) across. During solar maximum, the number of these spots rises, appearing in two bands, one either side of the equator. These active regions are often associated with solar flares and coronal mass ejections, which start to ramp up as solar maximum passes.

94
HALLEY'S COMET

The most famous object of its kind in the Solar System, records of this chunk of ice date back to 240 BCE, and it was present during the Battle of Hastings in 1066. It's in orbit around the Sun and returns to pass by Earth approximately every 79 years, making its most recent appearance in 1986. It's expected to return in 2061.


Key
● Halley's Comet
● Planet
1948
1961
Neptune
1926
1921
Uranus
1977
1983
Saturn
1915
Jupiter
1985
Mars
1986
Earth

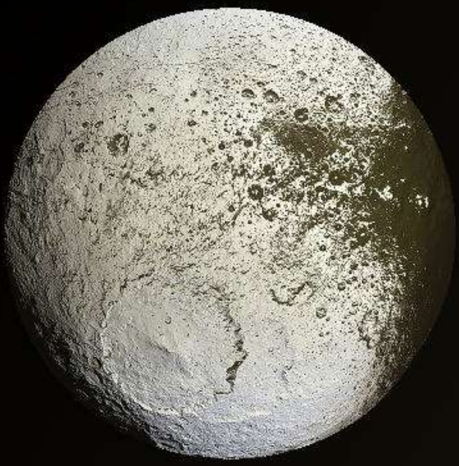


95
HUGE CANYON

Saturn's moon Tethys is scarred by a 2,000-kilometre (1,200-mile) long canyon called Ithaca Chasma that runs three-quarters of the way around its surface. The history behind its formation is unknown, but it's thought that the 100-kilometre (60-mile) wide crack could have formed as the moon cooled, or could have been created during the impact that left the vast Odysseus crater on its leading hemisphere.

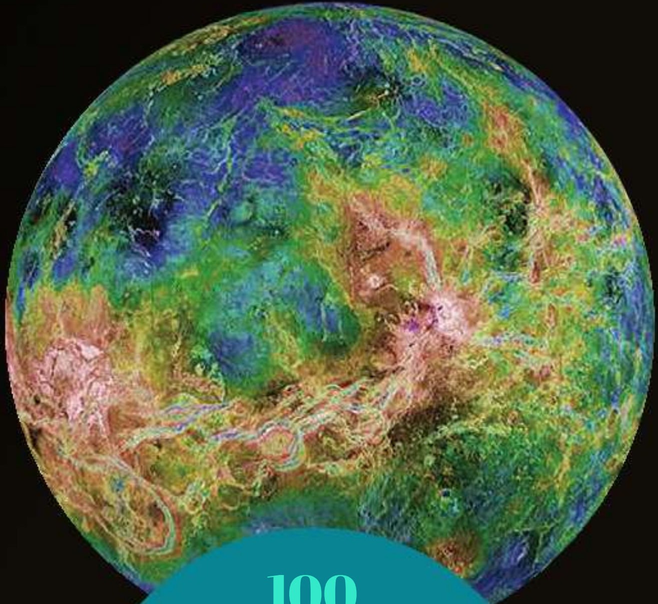
96
PAINTED MOON

The surface of Saturn's moon Iapetus is half black and half white, earning it the nickname 'painted moon'. Its strange colouration is thought to be down to debris sprayed onto its face by other moons. As the dark material is heated by the Sun, any ice trapped within it turns to vapour, leaving just the sooty debris behind and preventing the 'paint' being covered with bright ice.



97
GIANT RIVERBED

Baltis Vallis is a 6,800-kilometre (4,200-mile) channel on Venus. It's the longest in the Solar System, challenged only by the River Nile in Egypt, which measures around 6,650 kilometres (4,132 miles) from start to finish. At between one and three kilometres (0.6 and 1.8 miles) wide, Baltis Vallis is thought to have been formed by fast-moving lava flows and resembles a river in the way that it winds across the landscape.

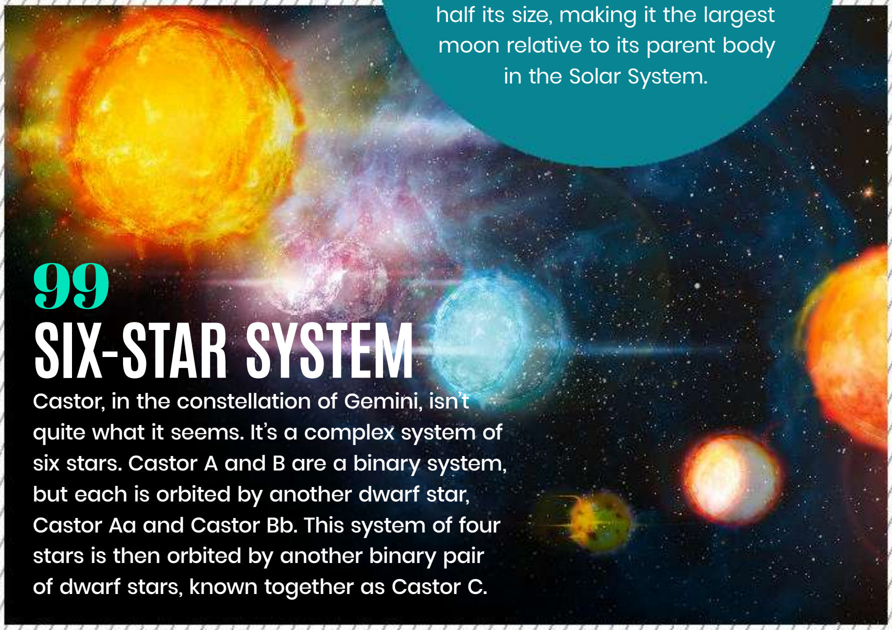


100
GIANT MOON

Despite its diminutive size, Pluto is still a wonder in its own right. The tiny ball of rock and ice would fit inside the US, but it manages to hold onto five moons. The biggest, Charon, is almost half its size, making it the largest moon relative to its parent body in the Solar System.

98 JEWEL BOX

NGC 3603 is home to one of the most massive clusters of young stars in the Milky Way. Just 20,000 light years from Earth, the open cluster is described by NASA as a 'stellar jewel box', with three truly massive Wolf-Rayet stars nestled at its core. The hot young stars have blown away their blanket of dust and are blasting the surrounding hydrogen gas with ultraviolet light, illuminating the clouds.



99
SIX-STAR SYSTEM

Castor, in the constellation of Gemini, isn't quite what it seems. It's a complex system of six stars. Castor A and B are a binary system, but each is orbited by another dwarf star, Castor Aa and Castor Bb. This system of four stars is then orbited by another binary pair of dwarf stars, known together as Castor C.

© NASA; Adam Evans; Tyrogthekreeper; ESA; ESO; Tobias Roetsch; Planck Collaboration; Arizona State University; JPL-Calltech; Peter Tuthill & James Lloyd; DLR; Steveroche; SSI;

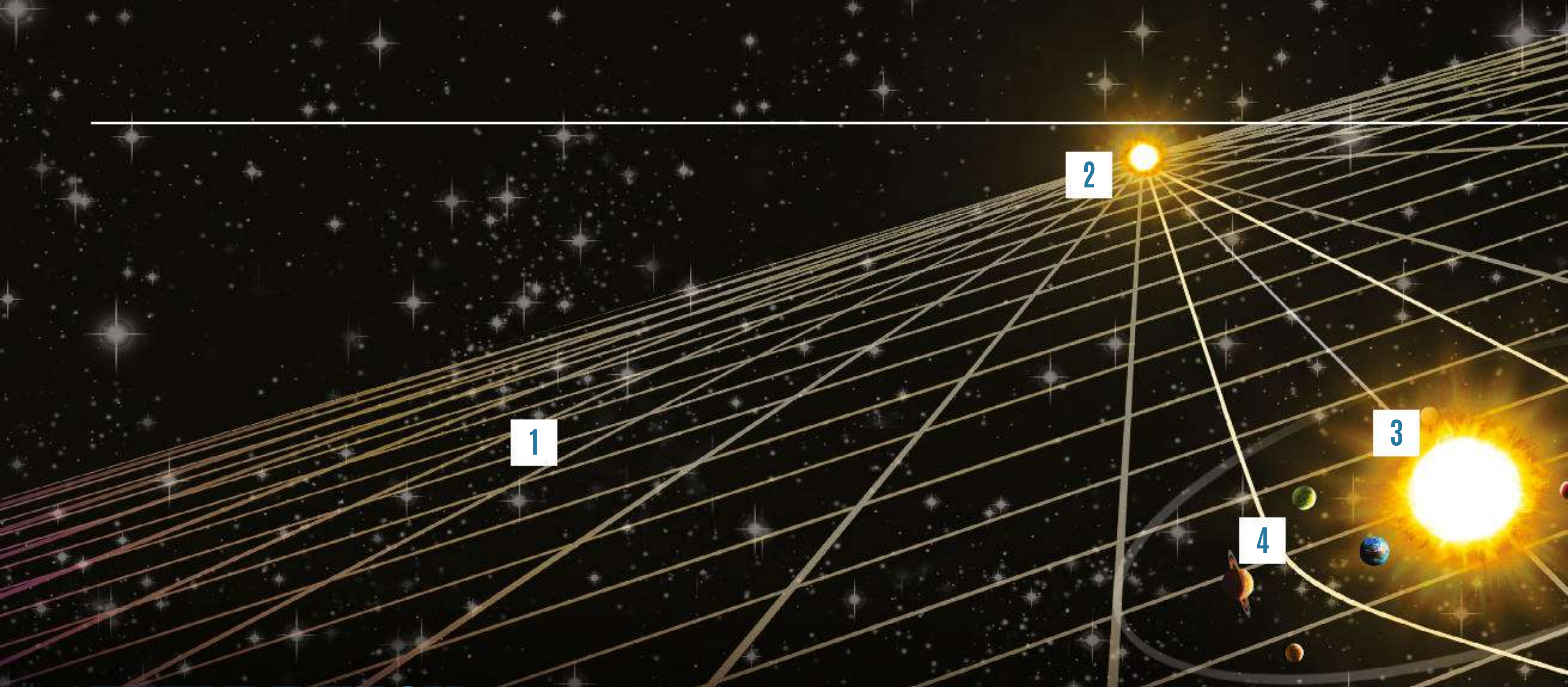
WORLD OF KNOWLEDGE

REAL CRIME
HISTORY OF WAR
BOMBER COMMAND
ALL ABOUT SPACE
100 WONDERS of the UNIVERSE
ALL ABOUT HISTORY
HOW IT WORKS
EXTREME EARTH

BUY YOUR ISSUE TODAY!

PRINT and DIGITAL subscriptions available at

www.magazinesdirect.com



FUTURE TECH

DEEP-ORBIT OBSERVATORY

We can use the Sun as a giant lens, but we'd need to send a telescope far into the Solar System

Using a technique called gravitational lensing, the Fast Outgoing Cyclopean Astronomical Lens (FOCAL) will enable us to see deeper into space than ever before. With the ability to view distant objects at huge magnifications, the telescope will be situated between 550 and 1,000 astronomical units (AU) from the Sun, which is the greatest area of magnification possible. Originally devised by SETI astronomer Claudio Maccone in a 1992 paper, FOCAL was formally proposed to the European Space Agency in 2000 and put forward by Maccone at the International Astronautical Congress (IAC) in 2010.

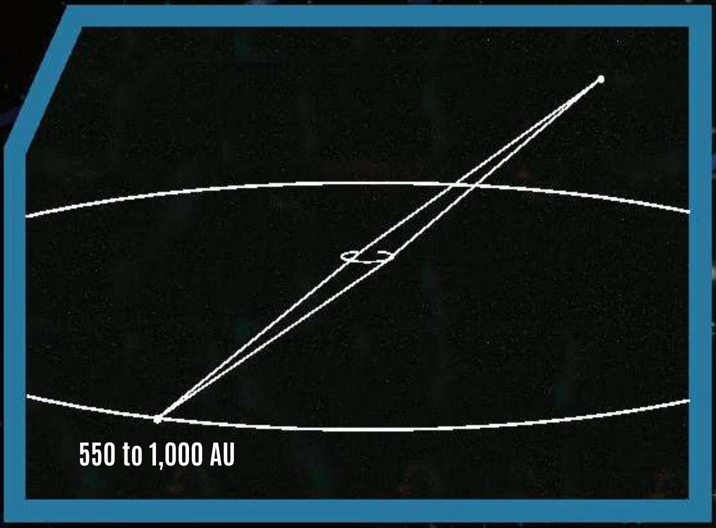
The telescope's magnification works by distorting space-time, an idea that was published in a 1936 paper by Einstein using his theory of relativity. This was improved upon in 1964 by Sidney Liebes' mathematical theory of gravitational focusing and then in 1978 by the discovery of twin quasars by astronomer Dennis Walsh.

It's essential that the probe's motion is studied within the context of special relativity, not classical Newtonian mechanics. This is because unlike Newton's teachings, Einstein explains that gravity can alter the direction of light and cause the lensing effects that will be so important to FOCAL. The probe must be sent in the opposite direction of the system we want to observe. This is to view the deflection angle created by incoming electromagnetic waves that pass outside the Sun, but within a certain distance of its centre. These are ideal for the FOCAL spacecraft to use as a lens to see into the outer reaches of space.

If we could harness the Sun's gravitational lens, we would be able see into the early universe and view distant exoplanets in systems like Alpha Centauri. Two of FOCAL's key targets include the Kuiper Belt and the Oort Cloud. Evidently, new systems of propulsion will have to be achieved to realise FOCAL, as the estimated distance to travel will be 14 times the distance from the Sun to Pluto.

The FOCAL spacecraft will use either a nuclear-powered electric propulsion system, a xenon-fuelled ion engine or an advanced type of solar power, as the velocity relative to Earth would have to be 100 kilometres (62 miles) per second to reach a distance of 1,000 AU in 50 years. When the craft

▼ FOCAL will be designed to see into deep space, but the first mission is to study the Oort Cloud and Kuiper Belt past Neptune



reaches its set destination, it will assess parallax distances, map the rotation curve of the galaxy, explain a star's stages of nuclear burning and make carbon stars visible. FOCAL could use a one-metre (3.3-foot) optical telescope with a ten-Watt laser transponder as an optical communications system that will transmit the data back to a satellite orbiting Earth.

With predictions that as many as 250,000 galaxies will be seen in the far-infrared and submillimetre wavelengths, Maccone claims that projects like FOCAL are "the next most important target that humankind must reach in order to be prepared for the successive and more difficult task of achieving interstellar flight".

1 Distant space

FOCAL will attempt to actively explore the Oort Cloud and Kuiper Belt in our Solar System to find celestial bodies similar to Pluto, or maybe Planet Nine.

2 Deep observation

The mission will see deeper into space than any human mechanism ever has before. New ideas of propulsion will be needed to realise this.

3 The Sun

The corona is a barrier to deep-space observation. Waves of light that pass through it are distorted by plasma, so the study angle must stay out of this zone.

4 Deflection angle

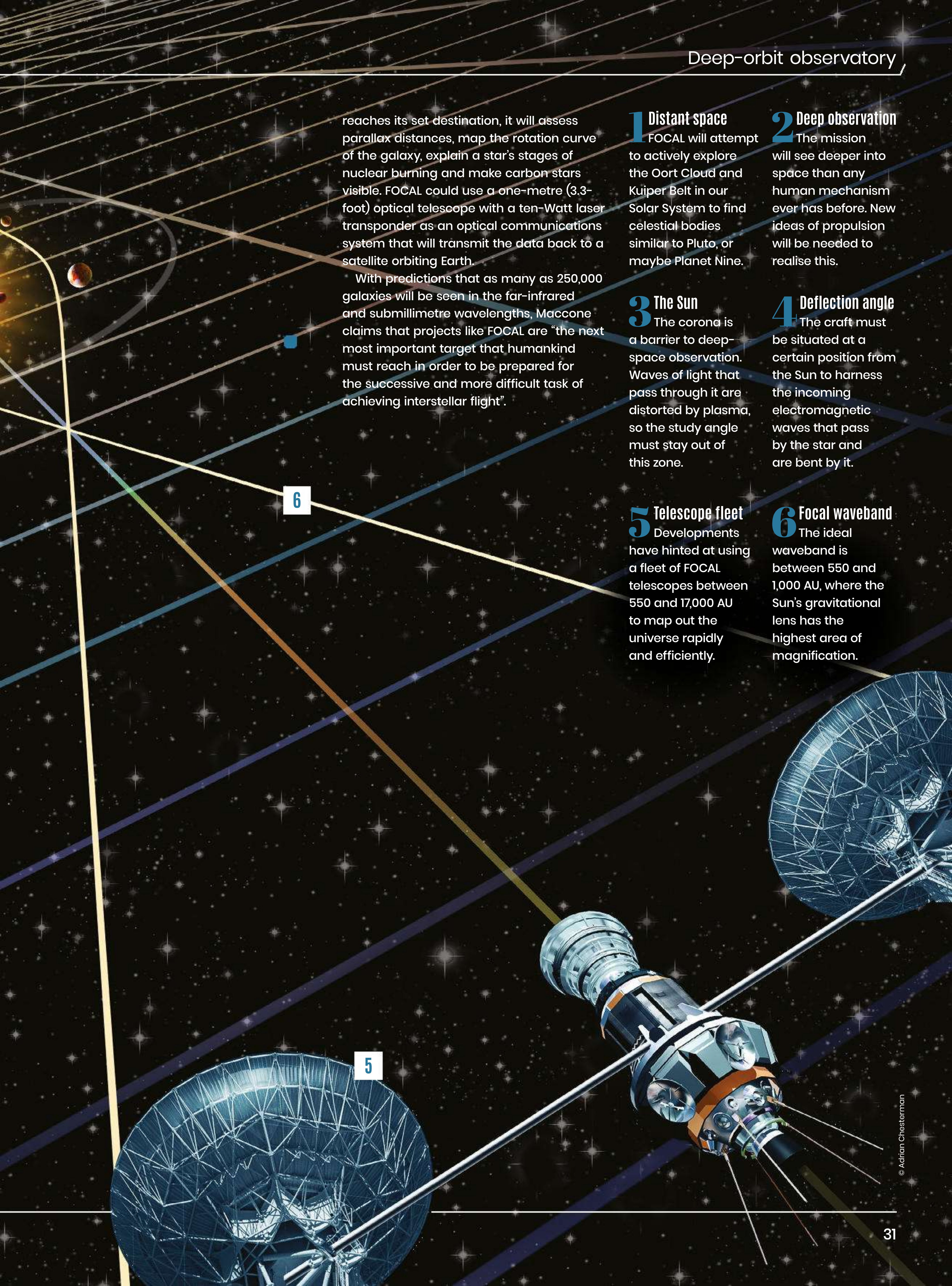
The craft must be situated at a certain position from the Sun to harness the incoming electromagnetic waves that pass by the star and are bent by it.

5 Telescope fleet

Developments have hinted at using a fleet of FOCAL telescopes between 550 and 17,000 AU to map out the universe rapidly and efficiently.

6 Focal waveband

The ideal waveband is between 550 and 1,000 AU, where the Sun's gravitational lens has the highest area of magnification.



© Adrian Chesterman

BIO+

Alex Teachey

Teachey is a distinguished postdoctoral fellow at the Academia Sinica Institute of Astronomy and Astrophysics in Taipei, Taiwan. Alex has been studying and searching for exoplanets and exomoons for many years now, scouring data collected by the Kepler Space Telescope. He has previously worked at both the American Museum of Natural History and the National Radio Astronomy Observatory.

Alex Teachey

"I expect it to be a habitable exomoon"

Sifting through data from NASA's Kepler, astronomers believe that we could have picked up the first signal of an alien moon. Co-discoverer and astronomer Alex Teachey reveals if we should be getting our hopes up

Interviewed by Lee Cavendish

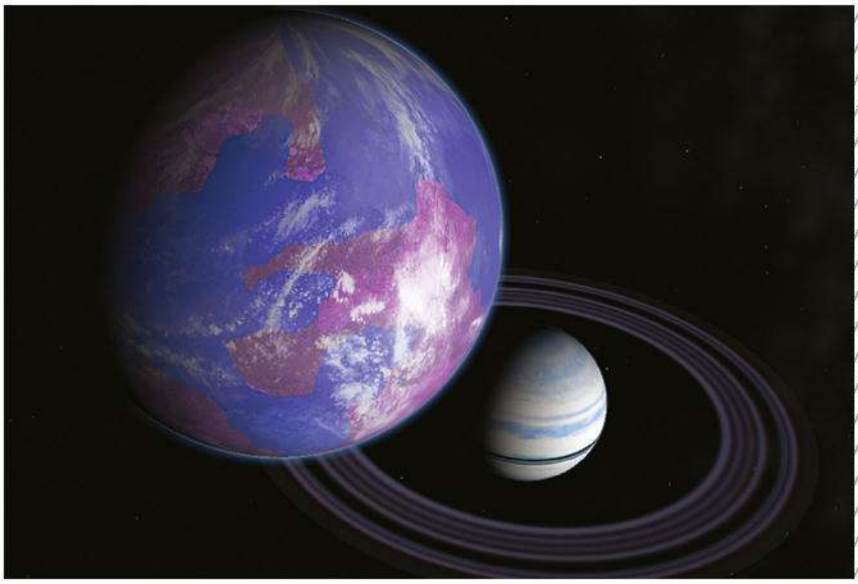
Why do think that exomoons play such an important role in understanding our universe?

I think that there's a couple of reasons why we're so interested in exomoons. First of all, I think that they could really tell us a lot about the formation of our Solar System and the formation of other solar systems. Certainly they tell us about the system we see them in, but the question always arises about life evolving on Earth. Were these circumstances on Earth very common across the galaxy, or were they very special? I think that it's very much an open question.

I think exomoons can play a part in answering that question because we've seen moons all over the place in our Solar System, and there's good reason to think they could be elsewhere. Until we see moons, it's very much an open question whether we've got an unusual formation history or whether this is something that happens all over the place.

I would say that we are still very much interested in the idea of habitable moons. The candidate we identified in our paper, I would expect it to be a habitable moon, as we think it's quite large. More generally, I think people are very much interested in these questions, because what if these moons are habitable? There are interesting places in our own Solar System, such as Europa, Enceladus, Titan and other places that are very intriguing, and could even be habitable. If similar moons turn out to be habitable in other parts of the galaxy, this expands the number of places where life could arise.

The search for an exomoon has been a tricky one, but it could hold important answers about our Solar System



▲ The Kepler Space Telescope searched for exoplanets from 2009 to 2018

How would you describe the signal you found from Kepler-1625b I, and how does that compare with an exoplanet signal?
When we look at exoplanets, we are looking for 'transits'. These are dips in the starlight we see when a planet passes in front of the star from our point of view. This is sort of a curved, trapezoid shape. When we're looking for the moons, we're looking for another dip in the transit associated with the moon. When the planet is blocking out starlight, the moon moves in front [of the star] and blocks the starlight as well. As you can imagine, as the planet is going around the star like clockwork, and the moon is going around the planet, every time you see the planet transit, the moon is probably going to show up in different places within the vicinity of the planetary transit.

What we were looking for was these dips due to the presence of the moon. That's what you'd expect to see if you saw a moon in your data, and that's what we think we saw in the Kepler-1625 system. I've been stressing all over the place that this is a candidate, but until we observe it with Hubble, it really isn't a sure thing. So far, in the tests we've run to rule out the presence of a moon, this system has passed all these tests. We think that the Kepler data is inconclusive. It's tantalising, but we really need the Hubble data to confirm the presence of this moon.

What has been done to rule out the possibility of it being an instrumental artefact?
There was an exomoon candidate that came along a few years ago. My former advisor, David Kipping, spent many years looking for exomoons. They thought they had found an exomoon candidate, and they starting looking at the individual pixels in Kepler's CCD image. After their analysis, what they thought was an exomoon signal was really just a weird thing to happen to the detector at that moment, so we definitely looked at that to try and rule it out.

If you have lots of transits to work with, you'll model some of the transits and leave some of the transits out of the model, then try to basically predict the morphology of those last transits. In other words, you build the model based on certain pieces of the data, and if that model is good, it should do well in fitting the data you haven't already fit through.

In this case we only had three transits, so what we had to do is split up the transits in half and fit it that way. It was a bit unusual to have to do it, because

▼ The now-defunct Kepler inside the Hazardous Processing Facility at Astrotech in Titusville, Florida there were so few transits, but the model seemed to work out very well. But if you give your model enough complexity, you can always find a better fit for the data – hence why you have to penalise that model to make sure you're accounting for that built-in error, and we definitely had to do that with the moon model. But even accounting for these sorts of things, the moon model seems to do pretty well.

What else could this signal be? Are 'blips' like these a common occurrence?

We tried to rule out the instrumental artefact as best as we could, and then in our proposal for observing with Hubble we also briefly examined other possibilities, like could this be a star spot? It can't really be a star spot, because that just wouldn't show up the way we're seeing it. I would say there's still a possibility that there could be some sort of instrumental strangeness that happened. I really do think we've done our due diligence, but there's always a chance that something got by us.

Also, there's something called 'detrending' – this is when you have long-term trends in the data that are from both from the instrument and subject of the star. You have to collect those out, and be pretty careful of how you do it. Basically, when you see a processed transit, it's mostly flat, and then there are these clear dips due to the planet. The real data doesn't look that way. There's a correcting process of the long-term trends you see in the data, so there's always a chance that something strange has happened in that process as well. The good news is that we've fit a model through the data. We seem to have a pretty good idea of what this moon would look like, and what that allows you to do is then project into the future. We now have some sort of prediction as to what we're looking for in future transits.

If we find a good fit, this would be really strong evidence that we've made a successful prediction. But at this point it's tough because there are so few transits. We only have three, and we definitely would have liked more than that. We're just approaching with an abundance of caution. Until we observe it with Hubble, we're not going to be totally convinced.

There are some people out there that make a prediction – I'm thinking of these 'Planet Nine' guys [Mike] Brown and [Konstantin] Batygin – and they are exceedingly confident in their predictions. I believe they even said they're positive that Planet Nine exists, and I'm sort of envious of their certainty! Until we observe this thing with Hubble, I'm not going to sleep easily, but we're optimistic. As I've said we've done our due diligence, but we have to wait and see.

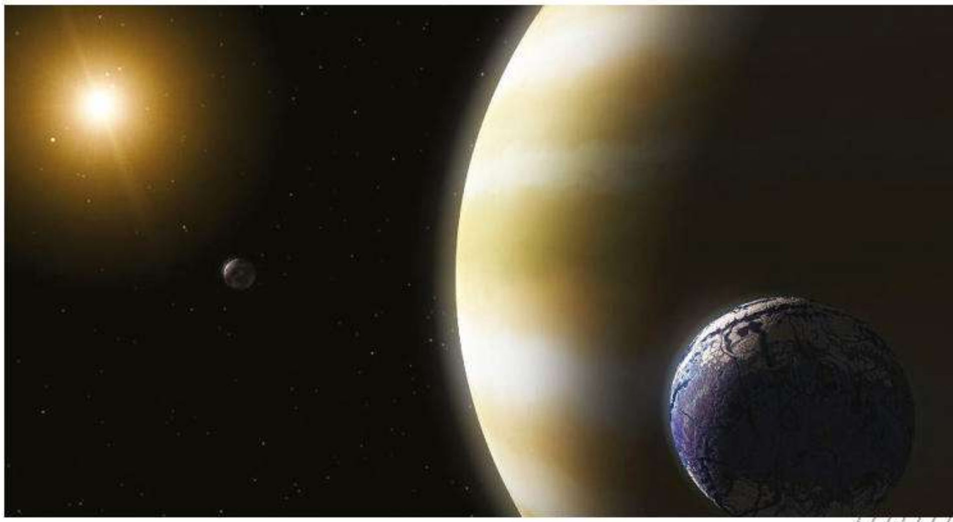
Have you been able to estimate or deduce any physical properties about Kepler-1625b's exoplanet and potential moon system?

I think we mentioned it briefly, but we're reluctant to go into great detail about it because these things could change when the Hubble observations come down. I'll point out that the star size changed from data release 24 to data release 25. The data didn't really change, but there was a new analysis for the size of the star. It went from being smaller than the Sun to larger than the Sun, and when you measure a transit, the dip in the starlight tells you the size of the planet in relation to the star. If the star gets bigger, the planet gets bigger.

The old estimate for the size of the star claimed the planet to be about half the size of Jupiter. Once the star got bigger with better data analysis, that made the planet about the size of Jupiter. It also made the moon much larger than it would have been otherwise. Before it would have been about the size of Earth, and then it would have been about the size of Neptune. This is based on the estimate for the stellar parameters. It's sort of an unusual system, not something we would have expected to see, and that again is a reason why we had some reservations about this thing.

How do you think exomoon exploration can be improved going forward?

I'll tell you the truth… it's going to be really tough. The thing about Kepler is that it was staring at one patch of the sky for around four-and-a-half years, and you really need at least two transits to characterise an exoplanet. That means a planet has to transit twice in four-and-a-half years, so these are going to be short-period planets close in to the star. It appears that moons are quite rare in that region, but that's perfectly in keeping with what we see in our own Solar System. All the big moons are in the outer Solar System. Kepler just wasn't able to probe that region at all.



An artist's impression of an exomoon around a large, gaseous parent planet

© NASA ; Jack Pfaller; MIT

> "If similar moons turn out to be habitable in other parts of the galaxy, this expands the number of places where life could arise"

FOCUS ON

WORK BEGINS ON NASA'S ASTEROID-HUNTING TELESCOPE

The infrared space telescope will search for potentially threatening near-Earth objects

Reported by Elizabeth Rayne

After recently passing a critical test, NASA's Near-Earth Object (NEO) Surveyor – an infrared telescope that will search for potentially threatening asteroids – has entered the building phase. NEO Surveyor is scheduled to launch in June 2028 and is the successor to the space agency's Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) mission, which discovered thousands of near-Earth objects and classified them as asteroids or comets. When NEO Surveyor launches, it will be the first mission to seek out multiple near-Earth asteroids at once. Some of its hardware and instruments are now being built so that the telescope can ultimately detect even faint asteroids. "NEO Surveyor represents the next generation for NASA's ability to quickly detect, track and characterise potentially hazardous near-Earth objects," Lindley Johnson, planetary defence officer for NASA's Planetary Defense Coordination Office, said.

The most important NEO Surveyor instruments that are now being developed are its hypersensitive infrared detectors, which will find distant asteroids that reflect infrared light. Earth's atmosphere blocks too much infrared light for telescopes on the ground to observe such objects. By orbiting in space, NEO Surveyor will have the advantage of being above the atmosphere, and its sunshield will block sunlight to allow the telescope to see objects coming from the direction of the Sun. The detectors also will be able to make out asteroids' shapes, compositions and rotations.

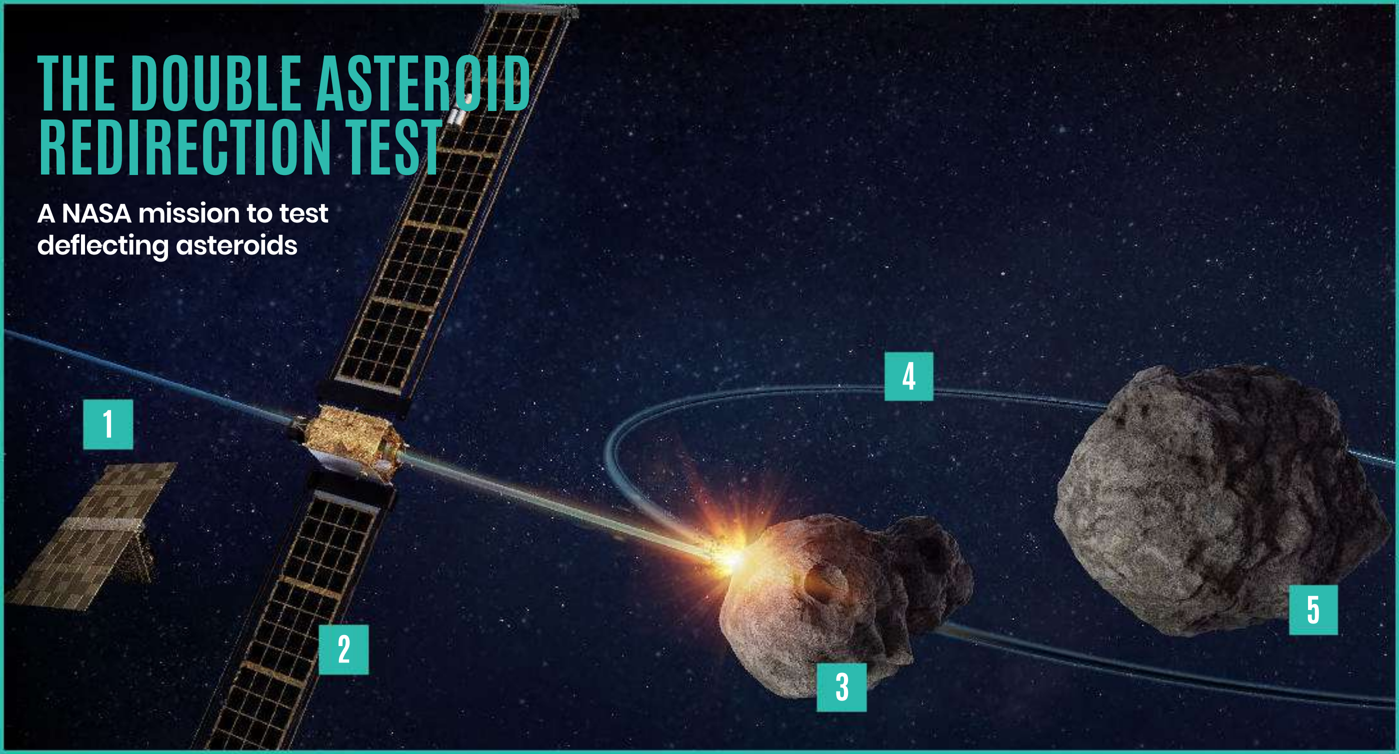
NEO Surveyor's radiators and struts are also being built to protect its infrared detectors, which will need to be kept cooler than the spacecraft's electronics. The new radiators can cool passively – as opposed to previous radiators that needed to be constantly active – and will be just as effective at keeping the spacecraft's instruments from overheating. The struts are made of material that doesn't conduct heat well so that they can divide the detectors from the rest of the spacecraft. This is critical because the sunshield will be especially hot from blocking sunlight. Also in progress are NEO Surveyor's beam splitters, enclosure, electronics and solid aluminium mirror.

NEO Surveyor is the next level up in detecting asteroids that may be on a collision course with our planet. NASA's recent Double Asteroid Redirection Test (DART) mission proved that it's possible to push an incoming asteroid slightly out of its orbit, but Mission Control needs to be aware of it first. This is how NEO Surveyor and its successors could save Earth from the fate of the dinosaurs in the future.

Ⓐ An artist's depiction of NASA's NEO Surveyor telescope looking for asteroids

THE DOUBLE ASTEROID REDIRECTION TEST

A NASA mission to test deflecting asteroids



1 What is DART?

The Double Asteroid Redirection Test (DART) slammed into an asteroid to assess the effect on that object.

2 First impact

DART marked the first time that humanity slammed an object in space with a kinetic impactor.

3 The target

DART's target was the double asteroid Didymos and its smaller 'moonlet', Dimorphos.

4 Why Didymos?

Didymos was selected for the mission because of its similarity to the asteroids that tend to threaten an impact with Earth.

5 Mission launch

Launched on 24 November 2021, the mission successfully impacted on 26 September 2022, changing the moonlet's orbit.

> "NEO Surveyor will have the advantage of being above the atmosphere"

ALL ABOUT SPACE | Subscription offer

ALL ABOUT SPACE

SUBSCRIBE FOR OUR BEST SAVINGS

SAVE 50%
HAVE WE FOUND THE FIRST EXOMOON?
ISSUE 140
MARCH 2023
ALL ABOUT SPACE
ANDROMEDA
CARTWHEEL GALAXIES
EXOPLANETS
SATURN'S RINGS
100 WONDERS of the UNIVERSE
THE DISCOVERIES AND INCREDIBLE PHENOMENA THAT HAVE REVOLUTIONISED OUR UNDERSTANDING OF THE COSMOS
GIANT LAVA RIVERBED
DIAMOND PLANETS
AURORAE
HISTORY OF SPACESUITS
GALAXIES, NEBULAE & STAR CLUSTERS: MARCH'S ULTIMATE DEEP-SKY TOUR
HEROES OF SPACE: ALEXEI LEONOV | WHY STARS WANDER | OUTER-SPACE OBSERVATORY
ALL ABOUT SPACE
100 WONDERS OF THE UNIVERSE

Reasons to subscribe...

- You'll never miss an issue!
- It's delivered direct to your door
- Brilliant value – great savings on the cover price
- Exclusive subscriber covers

100 WONDERS of the UNIVERSE
ANDROMEDA GALAXY
THE PILLARS OF CREATION
THE MOON
SOMBRERO GALAXY

HAVE WE FOUND THE FIRST EXOMOON?
ALL ABOUT SPACE
HISTORY OF SPACESUITS
ALL ABOUT SPACE
100 WONDERS OF THE UNIVERSE

Subscribe now

www.magazinesdirect.com/aas/AASBEST23
or call 0330 333 1113 and quote B25W

PRINT ONLY

£8.83 every three months

PRINT AND DIGITAL

£12.63 every three months

***Terms and conditions:** Offer closes 31 March 2023. Offer open to new subscribers only. Sign up to pay just £8.83 every three months. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. For full terms and conditions, visit **www.magazinesdirect.com/terms.** For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 8.30am to 7pm and Saturday 10am to 3pm UK time or e-mail: **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

THE HISTORY OF SPACESUITS

THE 60-YEAR EVOLUTION OF SPACE SURVIVAL TECH

Written by Jonathan O'Callaghan

These miniature spacecraft have allowed us to operate in space for over half a century

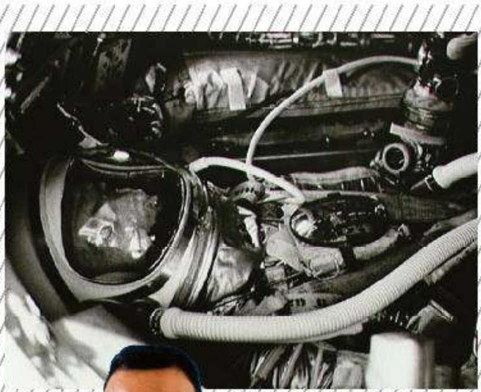
When the United States and the Soviet Union first decided to venture into the cosmos in the mid-20th century, it was readily apparent that they would need something to protect their explorers from the harshness of space. While pressure suits had been used before on high-altitude jets, no one was quite sure how the human body would cope with weightlessness, and particularly with the vacuum of space if a spacewalk was to be attempted.

One thing that was known for certain, however, was that exposure to space without a spacesuit would be fatal. 20 kilometres (12 miles) above Earth the atmosphere becomes so thin, and the atmospheric pressure is so low, that the water and blood in a human body will start to boil. Above this point, known as the Armstrong limit, some sort of protection is vital. Therefore the idea of a wearable spacecraft designed to protect its occupant from the harshness of space – now known as a spacesuit – was born.

Spacesuits come in a variety of shapes, sizes and uses. In the modern day on the International Space Station (ISS), astronauts wear flight suits for launch and re-entry that are largely designed to protect the occupant in case of a bailout. During a spacewalk they wear a much more sophisticated suit that allows them to operate in space.

Yuri Gagarin became the first man in space in 1961

Mercury suits were specially tailored to each astronaut



SK-1

First use:
Vostok 1, 1961

1 Helmet

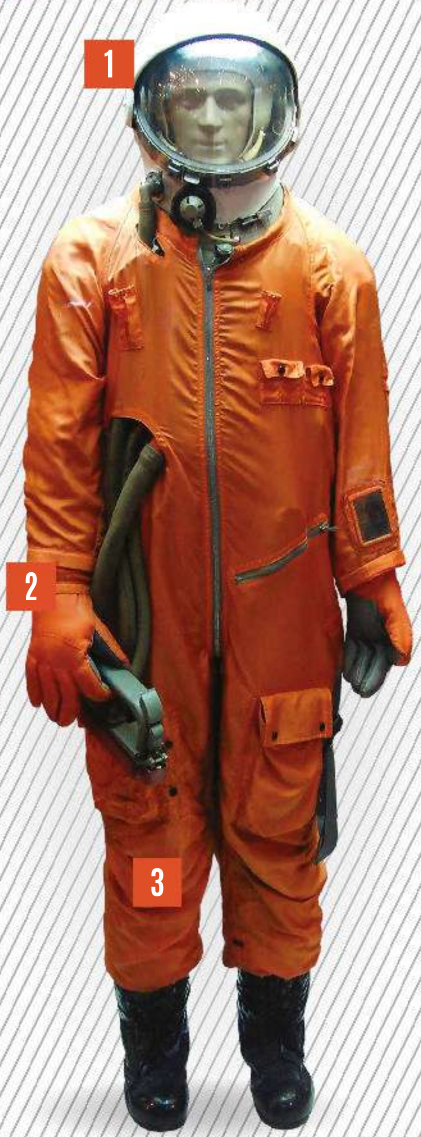
A helmet with a visor was attached to the suit, while an inflatable rubber collar could be used in the event of a water landing.

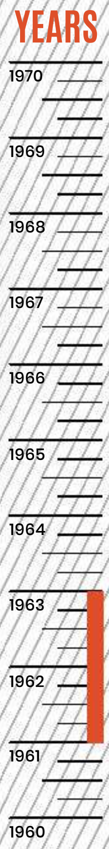
2 Weight

The SK-1 suit, which weighed 20 kilograms, was used for the first six Vostok missions, including Gagarin's historic first trip to space.

3 Basic design

The SK-1 was designed only to protect the cosmonaut during launch, orbit and re-entry, and not for spacewalks.





MERCURY

First use:
Freedom 7, 1961

1 Life vest

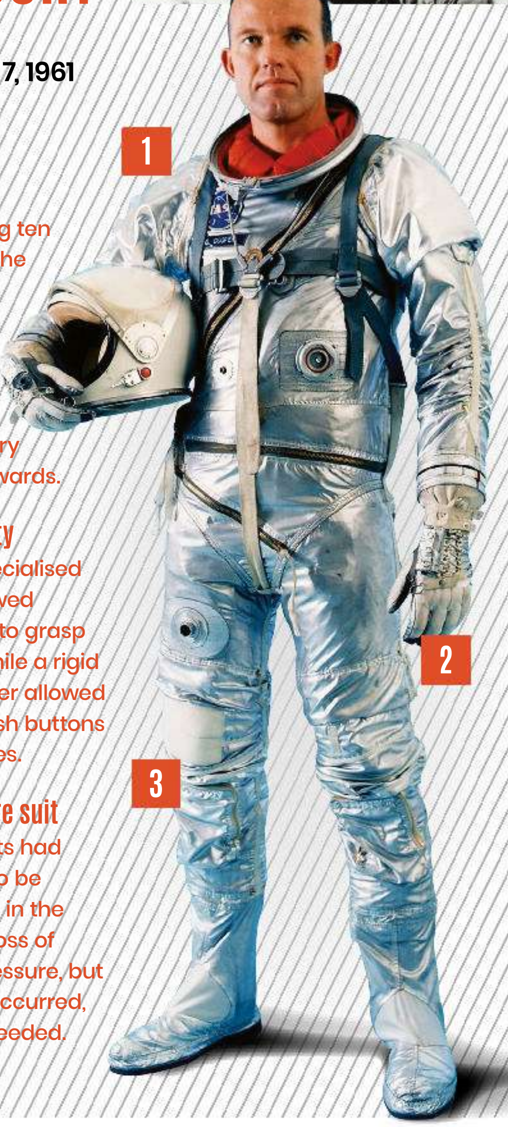
Weighing ten kilograms, the suit had an inflatable life vest attached from the third Mercury mission onwards.

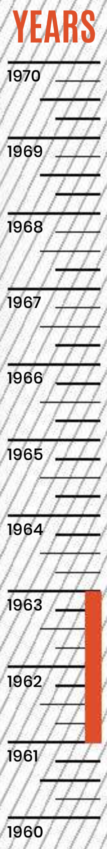
2 Dexterity

The specialised gloves allowed astronauts to grasp controls, while a rigid middle finger allowed them to push buttons and switches.

3 Pressure suit

The suits had the ability to be pressurised in the event of a loss of capsule pressure, but this never occurred, so wasn't needed.





While early iterations were bulky and basic, more modern spacesuits make use of computerised technology, cooling systems, movable joints and more to make operations in space more comfortable for astronauts. Future spacesuits, which are now in development for the Artemis program, will allow greater dexterity and movement than ever before, letting astronauts operate on the surface of another body such as the Moon, an asteroid or Mars.

While modern astronauts can generally wear what they want on the ISS, in the early days of spaceflight there wasn't room to get changed into different clothes or spacesuits on a spacecraft. The Soviet Union's Vostok and Voskhod spacecraft and the American Mercury and Gemini spacecraft were all small and cramped, designed largely to test various aspects of spaceflight in orbit but not designed for long stays in space. The prospect of switching attire was not tackled for some time; in fact, the first time a spacesuit was taken off during flight wasn't until December 1965 by astronaut James Lovell on the Gemini 7 mission.

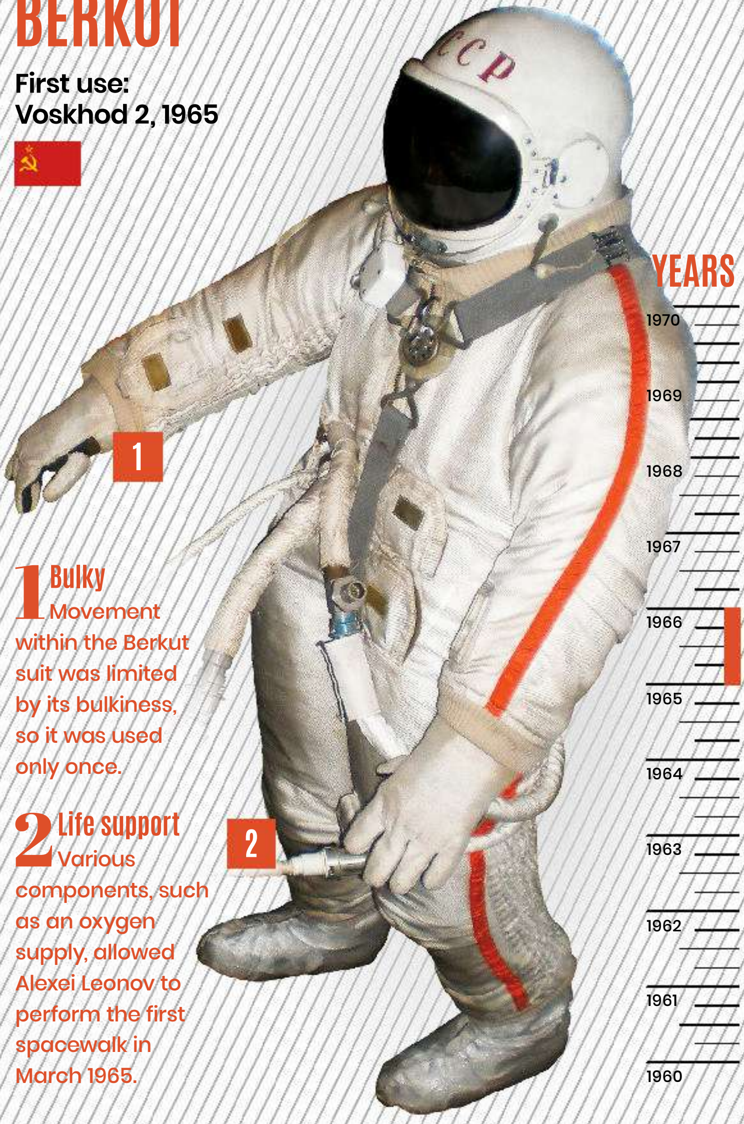
The first spacesuit was the one worn by Yuri Gagarin when he became the first human in space aboard Vostok 1 in April 1961. This was the Russian SK-1, which was basically a glorified pressure suit designed only to protect Gagarin during the flight and if he had to bailout – which, ultimately, he did upon re-entry – and not for a spacewalk. The Russian SK-1 was used from 1961 to 1963, with its last wearer being Valentina Tereshkova, the first woman in space, on the Vostok 6 mission, albeit a slightly modified version for a female known as the SK-2.

Leonov conducted the first-ever spacewalk while wearing a Berkut spacesuit

The Gemini was a significant upgrade on the Mercury suit

BERKUT

First use:
Voskhod 2, 1965

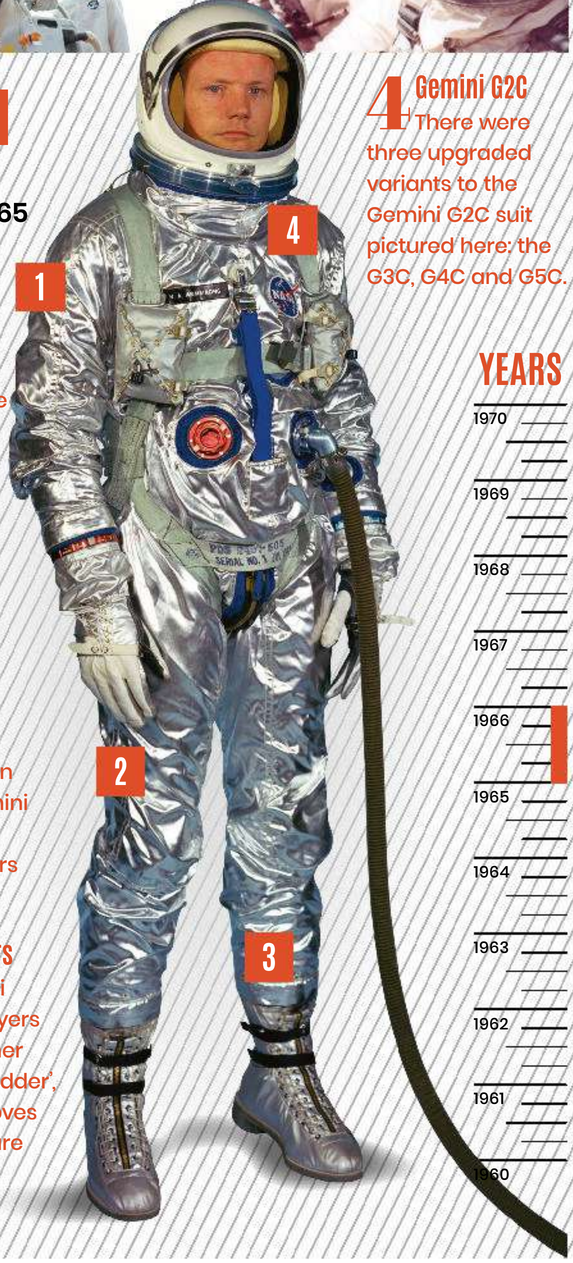


1 Bulky Movement within the Berkut suit was limited by its bulkiness, so it was used only once.

2 Life support Various components, such as an oxygen supply, allowed Alexei Leonov to perform the first spacewalk in March 1965.

GEMINI

First use:
Gemini 3, 1965



1 Movement The Gemini was a welcome upgrade, allowing astronauts to move more easily when pressurised.

2 Mylar Ed White performed the first American spacewalk in an upgraded Gemini G4C suit with additional layers of Mylar.

3 Nylon layers The Gemini suits had six layers of nylon, an inner rubberised 'bladder', detachable gloves and full-pressure helmets.

4 Gemini G2C There were three upgraded variants to the Gemini G2C suit pictured here: the G3C, G4C and G5C.

Hot on the heels of the Soviets in both spacecraft and spacesuits, the Americans had their own suit ready for the Mercury program. This was a derivative of the Navy Mark IV suit that had been used for high-altitude flights. It used a 'closed-loop' system to provide oxygen to the astronaut, had an aluminium-coated nylon exterior for thermal control and straps and zippers for a snug fit. The spacesuit could also be pressurised in an emergency in the case of sudden spacecraft depressurisation, but this never happened throughout the Mercury program.

The next spacesuit to arrive was arguably one of the most important ever designed. On the Voskhod 2 mission – the second and final flight of the short-lived Soviet Voskhod program – it had been decided that Alexei Leonov would attempt humanity's first spacewalk. The previous flight, Voskhod 1, had consisted of a three-man crew that was cramped into the Voskhod spacecraft. Somewhat dangerously, they flew without spacesuits as there wasn't space in the craft for all of the cosmonauts to wear one. Leonov, meanwhile, flew with just one other cosmonaut, and so was able to wear the Berkut spacesuit. This revolutionary suit, twice as heavy as the SK-1, allowed Leonov to operate outside the spacecraft for 45 minutes, although he ultimately only stayed outside for 12 minutes. But when Leonov tried to re-enter Voskhod 2, he found the suit had inflated too much, and he had to bleed pressure from it to get back in the spacecraft. Following these complications, it was decided to retire the Berkut spacesuit.

Once again, just behind the Soviets were the Americans with their Gemini spacesuit.

The Yastreb suit was only used once

YASTREB

First use: Soyuz 4 and 5, 1969

1 Movement

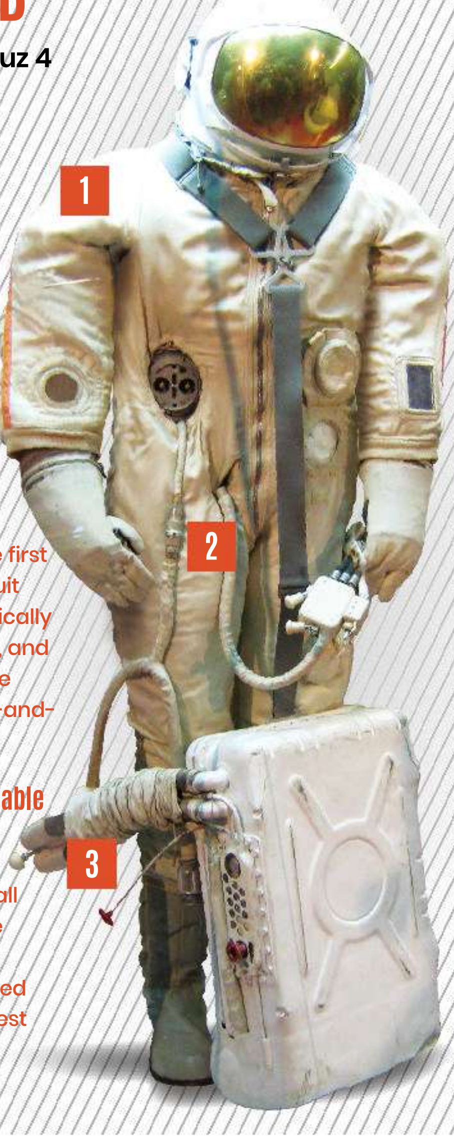
This spacesuit used pulleys and lines to make it much easier to move in than the Berkut spacesuit.

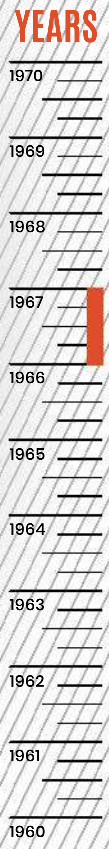
2 Life support

This was the first Russian spacesuit designed specifically for a spacewalk, and could provide life support for two-and-a-half hours.

3 Interchangeable

To allow the crew to move through the small Soyuz hatch, the backpack could either be mounted on the leg or chest of the suit.





KRECHET-94

First use: N/A

1 Self-righting

A metal 'hula hoop' on the back allowed cosmonauts to get up by rolling onto their side in case they fell over backwards.

2 Longevity

Weighing around 100 kilograms, the suit could operate by itself for ten hours before requiring a resupply.

3 Suitport

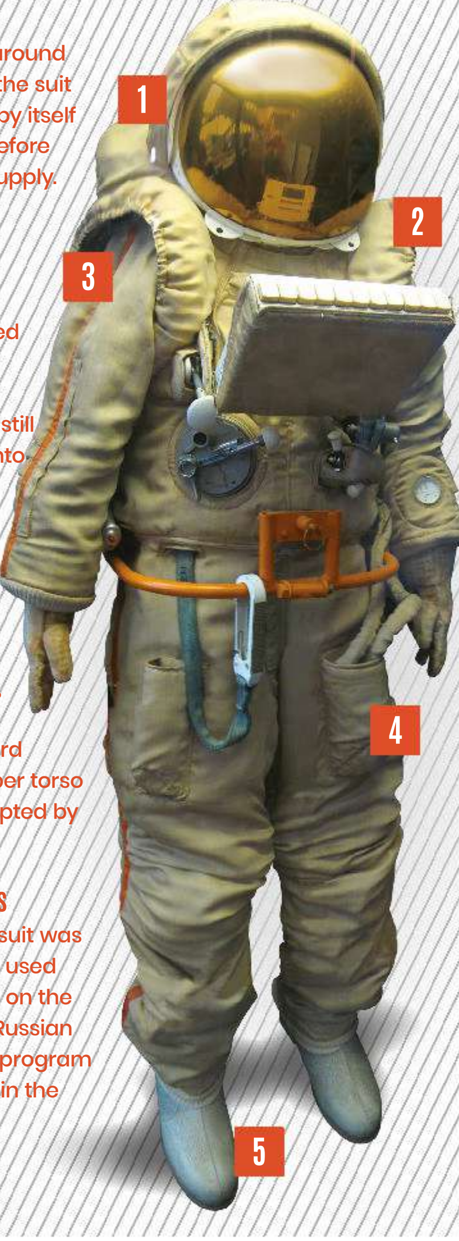
The first rear-entry suit, wearers climbed in through the back. This is a design feature still incorporated into modern suits.

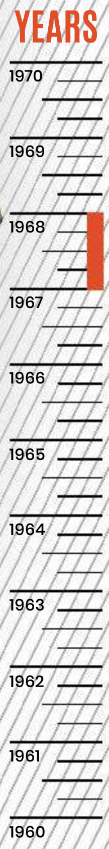
4 Innovative structure

This was also the first semi-rigid spacesuit, with soft fabric limbs and a hard aluminium upper torso – a design adopted by later suits.

5 Lunar walks

This spacesuit was designed to be used for spacewalks on the Moon, but the Russian manned lunar program was cancelled in the early 1970s.





Like the Berkut suit, this was designed to allow astronauts to operate in the vacuum of space – or at least one iteration of it was. Four different Gemini suits were designed: the G2C as a prototype suit, the G3C and G5C for launch and re-entry, and the G4C for spacewalking. Astronaut Ed White wore the G4C spacesuit when he completed the first American spacewalk in June 1965. Using layers of nylon, removable boots and a full-pressure helmet, the Gemini suits were a vital stepping stone to the Apollo suits that would be used to walk on the Moon.

Both the Americans and Soviets, however, found those early spacewalks very difficult. They required huge amounts of exertion, and astronauts and cosmonauts would often get back into their spacecraft approaching exhaustion, their suits full of sweat. As they were unable to get out of their spacesuit in their spacecraft, most of these early spacewalkers had to sit and wait until they returned to Earth to remove the uncomfortable apparel.

It was Buzz Aldrin who solved the conundrum of spacewalks on the Gemini 12 mission in November 1966. He suggested training astronauts underwater for the rigours of space, and also consulted on the addition of handrails and footholds to the exterior of spacecraft to give spacewalkers something to hold on to in space, reducing the exertion they needed to perform even simple tasks. Without the Gemini 12 mission, where Aldrin demonstrated effective operations in space, humans might not have been able to walk on the Moon.

Before Buzz Aldrin and Neil Armstrong walked on the lunar surface, however, the

APOLLO A7L

First use:
Apollo 7, 1968

1 On the Moon

The A7L – pictured here as a prototype – is most famously known as the one astronauts Neil Armstrong and Buzz Aldrin wore when they became the first humans on the Moon in July 1969.

2 Missions

The A7L was used for Apollo 7 to 14, while an upgraded version, the A7LB, which could last longer, was used on Apollo 15 to 17, the three Skylab missions and the Apollo-Soyuz Test Project.

3 Key features

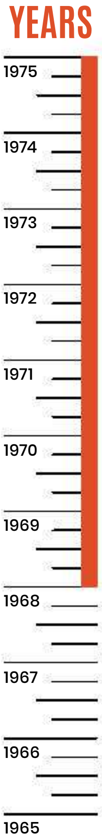
This suit had rubberised joints for movement, five layers of nylon and rubber for protection, 'link-net' meshing to prevent joints ballooning and metal rings to connect the helmet and gloves.

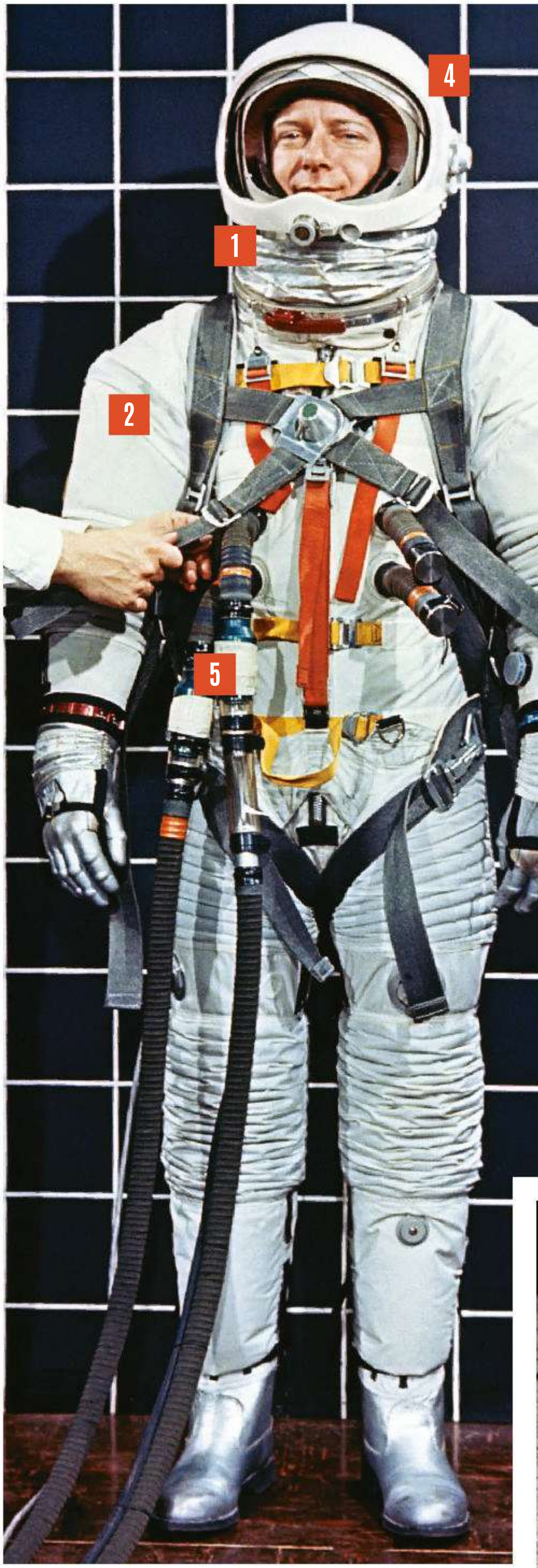
4 Fishbowl helmet

The famous 'fishbowl' helmet was incorporated by NASA on the A7L to allow for an unrestricted view. It's been used on all of NASA's spacesuits ever since.

5 Life support

The entire A7L suit, including the backpack which included over six hours of independent life support, weighed about 90 kilograms.



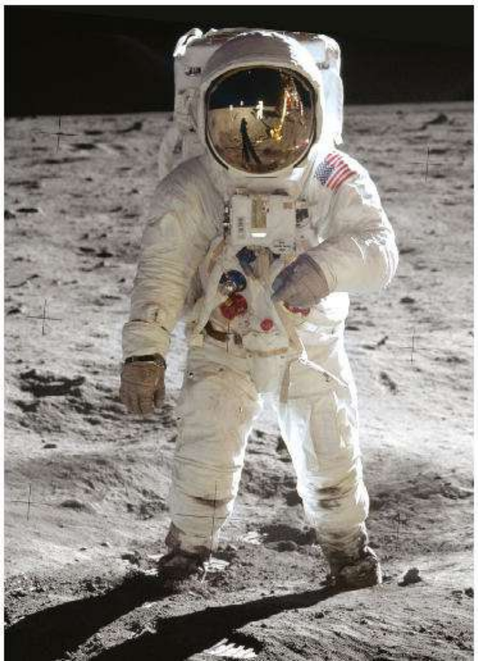


THE STORY OF THE A7L

Apollo led to the creation of one of the most iconic spacesuits: the Apollo A7L. The A7L was introduced by a fashion company called International Latex Corporation (ILC) who had been approached by NASA to design the suit alongside aerospace company Hamilton Standard. The latter grew suspicious of ILC's competence and designed its own suit called Tiger, which was submitted to NASA for the Apollo missions. It was a flop; Hamilton Standard blamed ILC and the fashion company lost its contract with NASA in 1962.

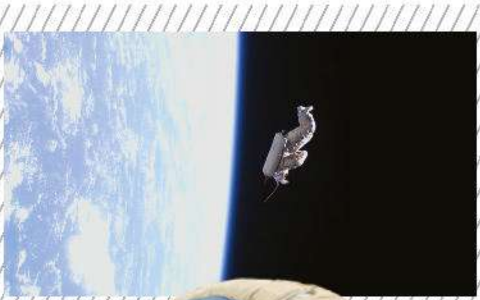
Several years later, NASA ran a competition for a new suit. A dozen ILC employees took their original designs from their old offices. They finished the suit and submitted it to NASA, and the A7L was born. Since then, ILC has made the modern EMU suit, designed NASA's next-gen Z-1 suit and even the air bags for NASA's Mars rovers Sojourner, Spirit and Opportunity that allowed them to land on the surface of Mars.

Buzz Aldrin on the Moon in the Apollo A7L



The Sokol suit is not suitable for spacewalks

In 2006, a retired Orlan suit called SuitSat-1 was released into orbit from the ISS



SOKOL

First use:
Soyuz 12, 1973

1 Purpose

The Sokol suit is used during re-entry and landing only.

2 Protection

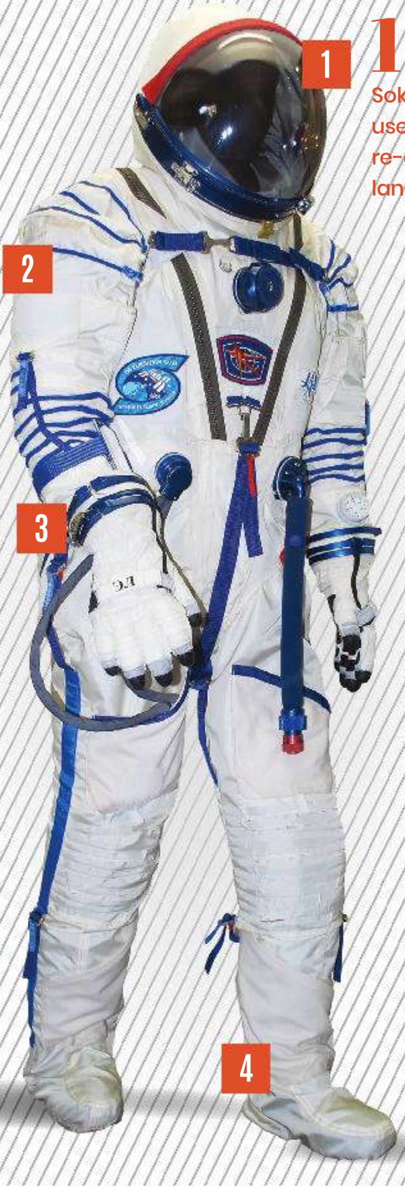
In the event of spacecraft depressurisation, the Sokol suit is designed to offer protection to cosmonauts for up to two hours.

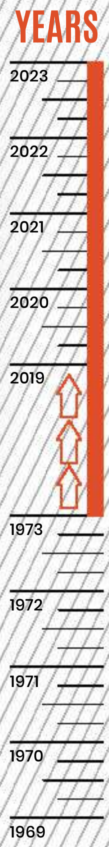
3 Layers

This suit has been upgraded; the Sokol KV-2 has an inner layer of rubberised nylon and an outer layer of white nylon canvas.

4 Boots and gloves

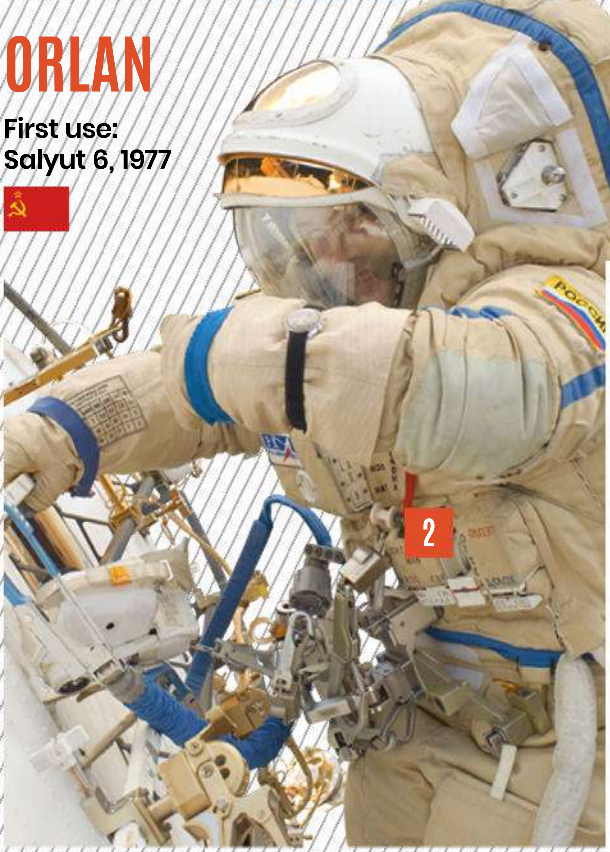
The boots are built in to the suit, while the gloves can be removed and reattached using wrist couplings.

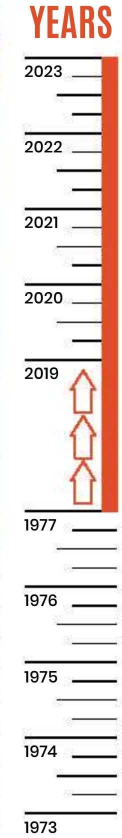




ORLAN

First use:
Salyut 6, 1977





1 Quick entry

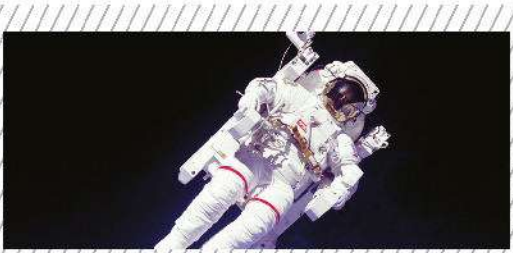
The Orlan suit makes use of a rear-entry system through the backpack that allows astronauts and cosmonauts to don the suit in just five minutes.

2 LCD screen

The main improvement of the modern Orlan-MK suit is that it has a mini-computer which processes data and alerts the wearer to malfunctions on a chest-mounted LCD screen.

Soviets were developing their own spacesuit to be used on the Moon. First they aimed to perfect the art of spacewalking with Yastreb. This spacesuit, with input on its design from Leonov, was a clear upgrade over the previous Berkut suit. It used pulleys and lines to assist with movement, and was generally much more manoeuvrable. It was used only on a crew exchange between Soyuz 4 and 5 in 1969, with the other Soyuz missions not using pressure suits. Yastreb's successor was Krechet-94, another revolutionary Soviet suit intended for lunar spacewalks. Its major innovations were a rear-entry hatch, known as a suitport, and a semi-rigid design. Both of these concepts have been incorporated into modern spacesuits. When the Soviet lunar program was cancelled, however, Krechet-94 was scrapped without a single flight under its belt.

NASA, meanwhile, had been hard at work on its own lunar suit. The Apollo A7L spacesuit was a huge step up from the Mercury and Gemini spacesuits, providing additional levels of comfort, protection and manoeuvrability that were unmatched before. Designed by ILC Dover, its primary purpose was ultimately to allow astronauts to operate effectively on the surface of the Moon. With 12 successful moonwalkers donning the suit, it was a resounding success. An A7L was tailor-made to each astronaut, but every Apollo mission actually required 15 suits, even though there was only a primary crew of three. This is because of the primary crew, each astronaut had three suits: one for flight, one for training and one for backup. The remaining six suits for each mission came from the backup



Bruce McCandless II performed the first of three flights of NASA's Manned Maneuvering Unit (MMU) in 1984

EXTRAVEHICULAR MOBILITY UNIT

First use:
STS-6, 1983

1 Comfort

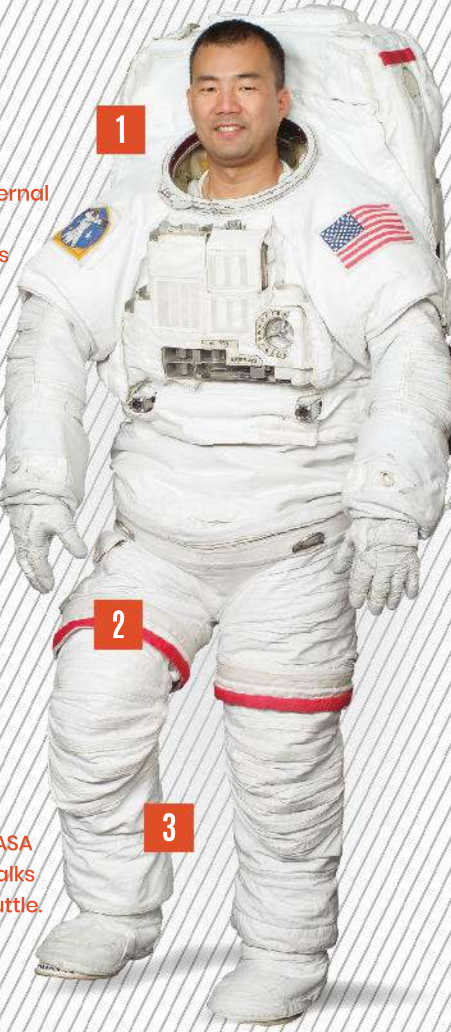
Under the external suit are urine collection devices (UCDs) and liquid-cooling and ventilation garments (LCVGs).

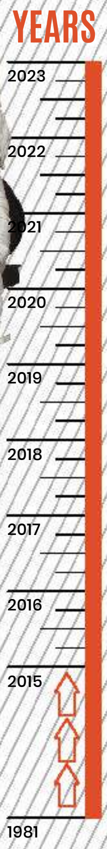
2 Identity

The red stripes help ground control differentiate between the astronauts when they're out on spacewalks.

3 Shuttle EVAs

This is the spacesuit that NASA used for spacewalks on the Space Shuttle.





This blue suit was used from STS-5 in 1982 until 1986's Challenger tragedy

SHUTTLE EJECTION ESCAPE SUIT

First use:
STS-1, 1981

1 Four missions

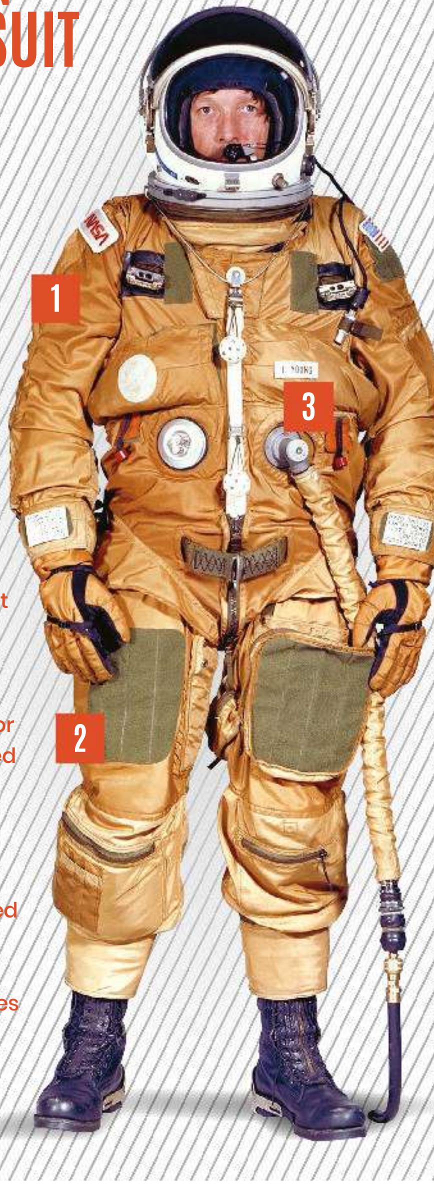
This suit was used only for the first four NASA Space Shuttle missions, before being replaced by LES and ACES.

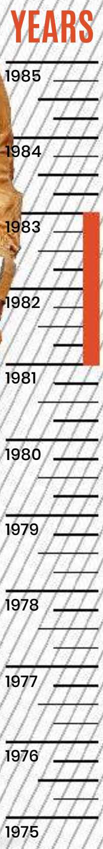
2 Ejection

The Shuttle Ejection Escape Suit was designed to protect astronauts in the event of ejection until ejector seats were removed from the craft after STS-4.

3 Survival

This suit allowed crew members to survive an ejection up to 24.4 kilometres (15.2 miles) high at speeds of up to Mach 2.7.





crew – each of them needed two suits, one for flight and one for training. For Apollo 11 through 17, a total of 105 suits were made. An upgraded version of the spacesuit was also used for all three manned missions to the Skylab space station.

With their cancelled lunar program behind them, the Soviets set about designing two new spacesuits, one for launch and re-entry and the other for spacewalking. Both of these spacesuits would be so successful that they would become the cornerstone of Soviet – and later Russian – space exploration. The Sokol spacesuit was a lightweight pressure suit that astronauts wore, and still wear, on the Soyuz spacecraft during launch and re-entry. These suits were the direct result of a tragedy when the three-man crew of Soyuz 11 was killed on 30 June 1971 as a result of their spacecraft depressurising on re-entry. They were unable to wear pressure suits as the spacecraft was too small, and therefore they were killed instantly. A redesign of the Soyuz spacecraft followed, with the number of crew reduced from three to two to allow them to wear suits during launch and re-entry. It wouldn't be until 1980 that three people would travel in a Soyuz again, when the spacecraft was big enough to support three astronauts in pressure suits.

The Soviets' other suit was the Orlan, a versatile spacewalking suit that, although upgraded over the years, is still in use today. In fact, the Chinese used it as the basis for the design of their Feitian suits that they use for their current spaceflights. It has a rear-entry port, allowing people to don it in minutes, and is semi-rigid, with a solid

The LES was used after the Challenger disaster

LAUNCH ENTRY SUIT

First use:
STS-26, 1988

1 Communications

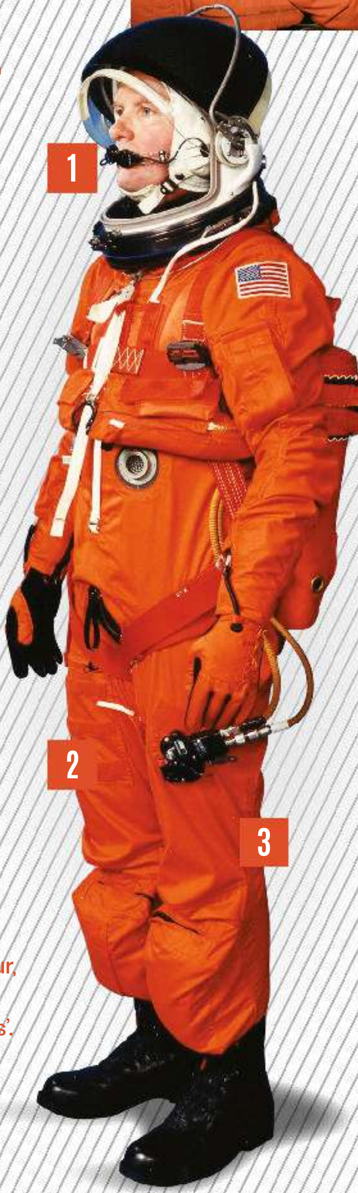
An additional new communications cap allowed the Space Shuttle crews to talk to ground control during launch and re-entry.

2 Nomex layer

It had a Nomex outer layer and was entered by crew using a rear-entry zipper. The helmet design also meant astronauts had to wear a communications cap.

3 Visibility

Owing to their colour, LES and ACES were also known as 'pumpkin suits'. The orange colouration helped the suit be spotted in case of an ejection into water.



The crew of the STS-121 mission to the ISS

ADVANCED CREW ESCAPE SUIT

First use:
STS-64, 1994

1 Upgraded suit

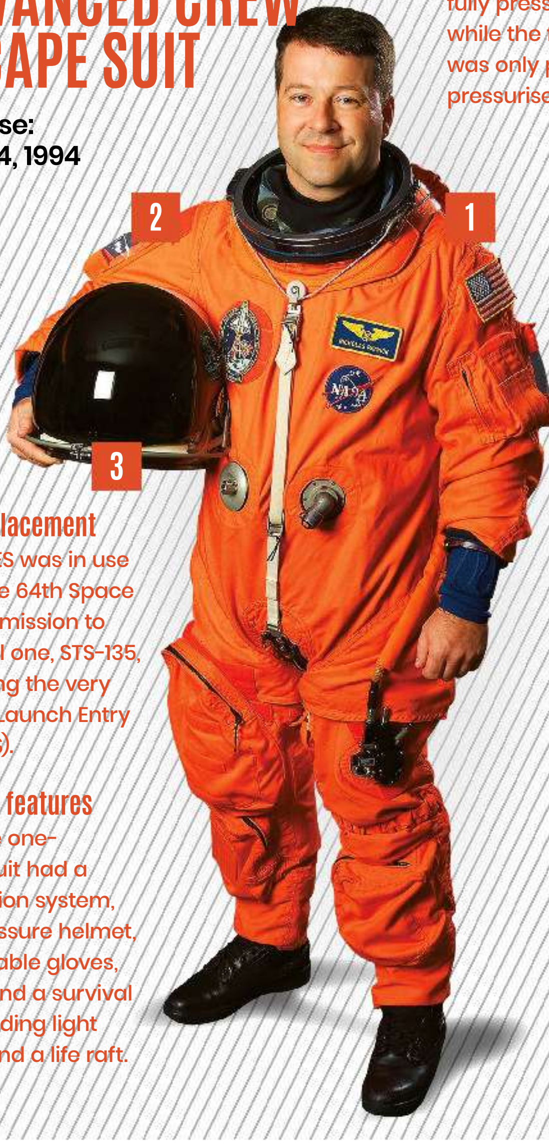
The main difference between LES and ACES was that the latter was fully pressurised, while the former was only partially pressurised.

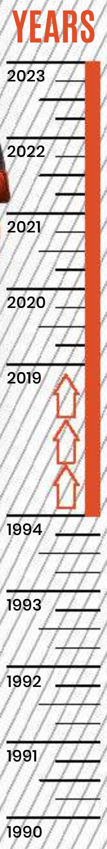
2 Replacement

ACES was in use from the 64th Space Shuttle mission to the final one, STS-135, replacing the very similar Launch Entry Suit (LES).

3 Key features

The one-piece suit had a ventilation system, full-pressure helmet, detachable gloves, boots and a survival kit including light sticks and a life raft.





torso and flexible arms. It's been used in the modern era for spacewalks on the ISS, having previously been used both on the Salyut and Mir space stations. The only other spacesuit designed by the Russians was the Strizh suit, which was developed to be used on the Russian Buran space shuttle. Like their earlier lunar program, this was scrapped, although the suit was lucky enough to have one flight on a mannequin during an unmanned test flight in 1988.

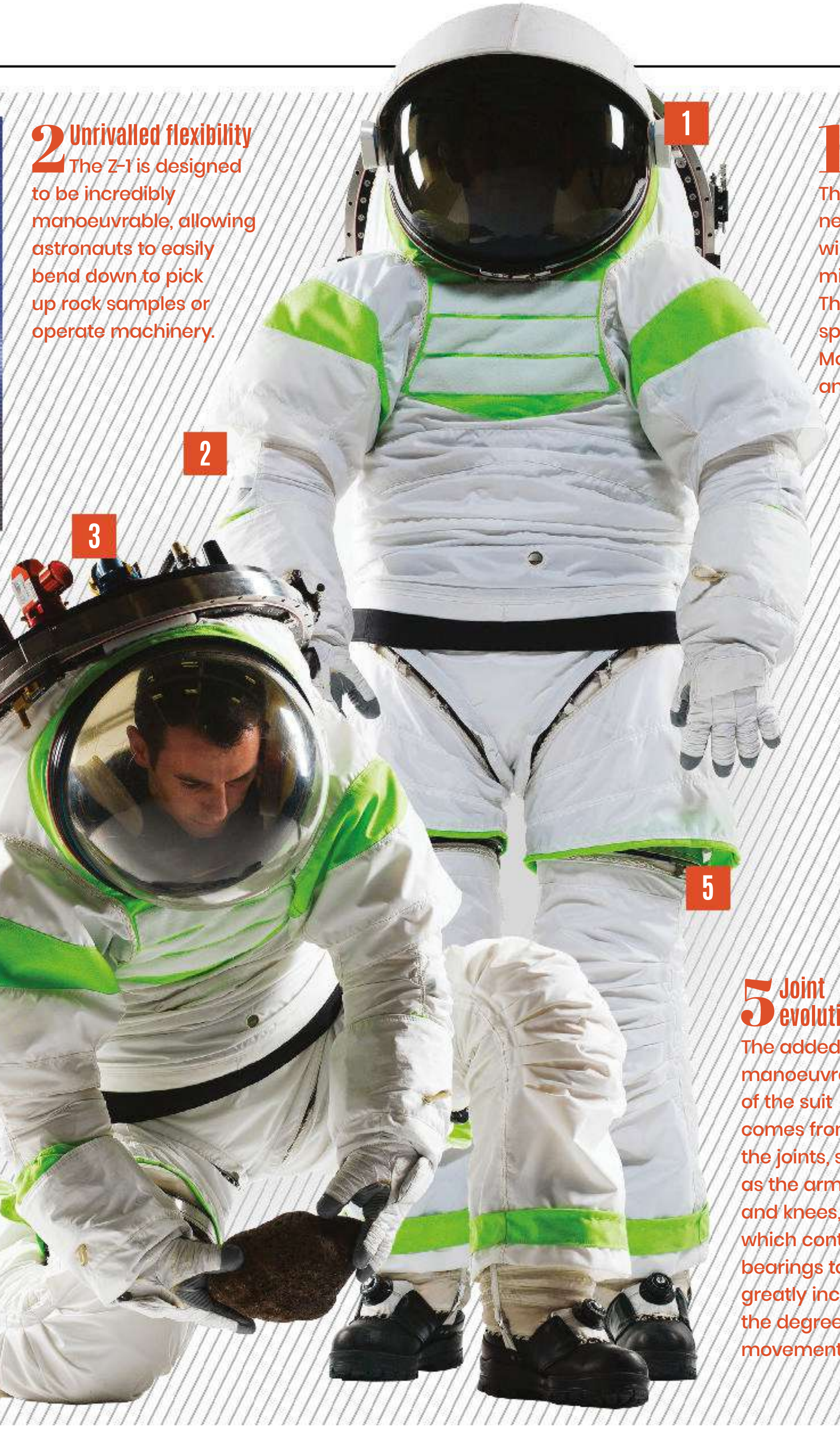
America also settled on a preferred series of spacesuits. In the early 1980s, the Extravehicular Mobility Unit (EMU) was introduced, originally to be used on spacewalks outside the Space Shuttle and later on the ISS. In tandem with this was the Shuttle Ejection Escape Suit that was used on the Space Shuttle as a launch and re-entry suit. It was scrapped after the fourth Space Shuttle mission in favour of regular flight suits, while the Challenger disaster in January 1986 prompted the design of the iconic orange Launch Entry Suit (LES), and later the Advanced Crew Escape Suit (ACES), which were both used for the remaining Space Shuttle missions until it was retired in July 2011.

Despite the relative advances in spacesuit technology, operating in space is still no easy feat. It's slow going, and even installing a simple component on the exterior of the ISS can take several hours. To assist astronauts and cosmonauts, the gloves of a spacesuit often have rubberised fingertips that help with grip, while loops allow tools to be tethered to the gloves. Tools can also be stored on the torso of the spacesuit, while a number of dials and switches on the front of

Ⓐ Front view of NASA's Z-2 spacesuit

Z SERIES

First use: Future



1 Built for a new generation

The Z-1 is NASA's new spacesuit that will be used for missions after 2015. These could include spacewalks on the Moon, an asteroid and Mars.

2 Unrivalled flexibility

The Z-1 is designed to be incredibly manoeuvrable, allowing astronauts to easily bend down to pick up rock samples or operate machinery.

3 Innovative suitport

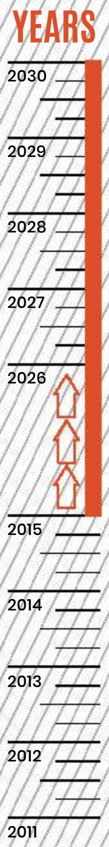
One major innovation is that, like Russia's Orlan spacesuit, astronauts will be able to enter the Z-1 through a rear-entry hatch.

4 Walking on Mars

The Z-1, which can be left outside a spacecraft for astronauts to climb into, will be used both for walks in the zero-gravity of space and on the surface of another world.

5 Joint evolution

The added manoeuvrability of the suit comes from the joints, such as the arms and knees, which contain bearings to greatly increase the degree of movement.



© NASA / Alamy / Science Photo Library / Wiki: Mikhail Shcherbakov, Tyrol5, Craigboy

the suit allow astronauts to regulate their temperature, pressure and more.

These complex machines have been vital in allowing astronauts to operate effectively and safely in space for over 60 years. While early space missions involved limited stays of just minutes in space, modern-day astronauts rely on their spacesuits for hours at a time as they work on the exterior of the ISS, and without spacesuits, extravehicular activities (EVAs), or spacewalks, would simply not be possible. And without the complex spacesuits designed for the Apollo missions, astronauts would also not have been able to walk on the Moon. Spacesuits have allowed us to study and explore space like never before, and their continued evolution and development will allow us to ultimately set foot elsewhere in the Solar System in decades to come.

> "Without spacesuits, extravehicular activities would simply not be possible"

Jonathan O'Callaghan
Science journalist
A freelance writer specialising in astronomy, astrophysics and space exploration, Jonathan was awarded the Walter Sullivan Award for Excellence in Science Journalism.

FOCUS ON

THE FIRST GALAXIES MAY HAVE FORMED MUCH EARLIER THAN WE THOUGHT

The finding has been revealed by the James Webb Space Telescope

Reported by Samantha Mathewson

NASA's James Webb Space Telescope has revealed dozens of galaxies that could be among the earliest known in the universe. Using early observations from the telescope, astronomers looked for galaxies at very high redshifts, which would indicate that these galaxies formed earlier in the universe. The team detected 87 galaxies that may have been the first to appear in the universe, about 200 to 400 million years after the Big Bang. “Finding such a large number of galaxies in the early parts of the universe suggests that we might need to revise our previous understanding of galaxy formation,” said Haojing Yan, an astronomer at the University of Missouri. “Our finding gives us the first indication that a lot of galaxies could have been formed in the universe much earlier than previously thought.”

The team looked for redshift in the infrared light captured by Webb. This allowed them to measure how far away the galaxies are by looking at how the colours change in the waves of light they emit. Since the Big Bang, the universe has undergone nonstop expansion, meaning the galaxies we observe are moving away from us. The higher the redshift, the farther away a galaxy is from us. And because the light from other galaxies takes a long time to reach us, the more distant a galaxy is, the earlier in time we see it. As such, looking for galaxies at very high redshifts provides insight into the early universe.

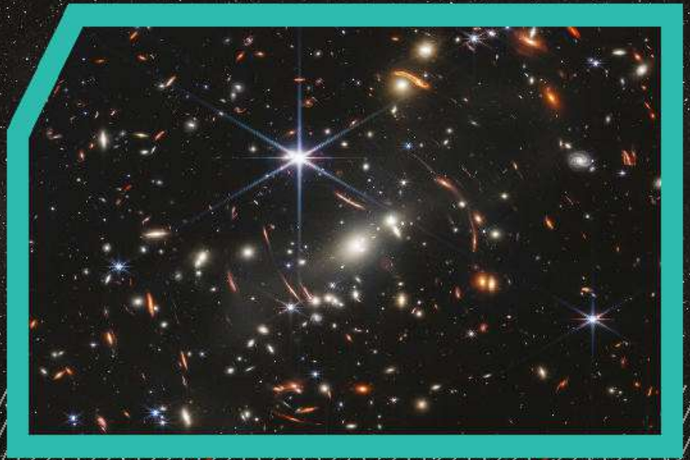
Objects at high redshifts of 11 and above can be detected only by infrared light, which is why Webb was crucial in observing these 87 galaxies. By comparison, the Hubble Space Telescope sees only from ultraviolet to near-infrared light, which is why astronomers previously thought there were very few galaxies beyond redshift 11. “I believe this discovery is just the tip of the iceberg because the data we used only focused on a very small area of the universe,” Yan said.

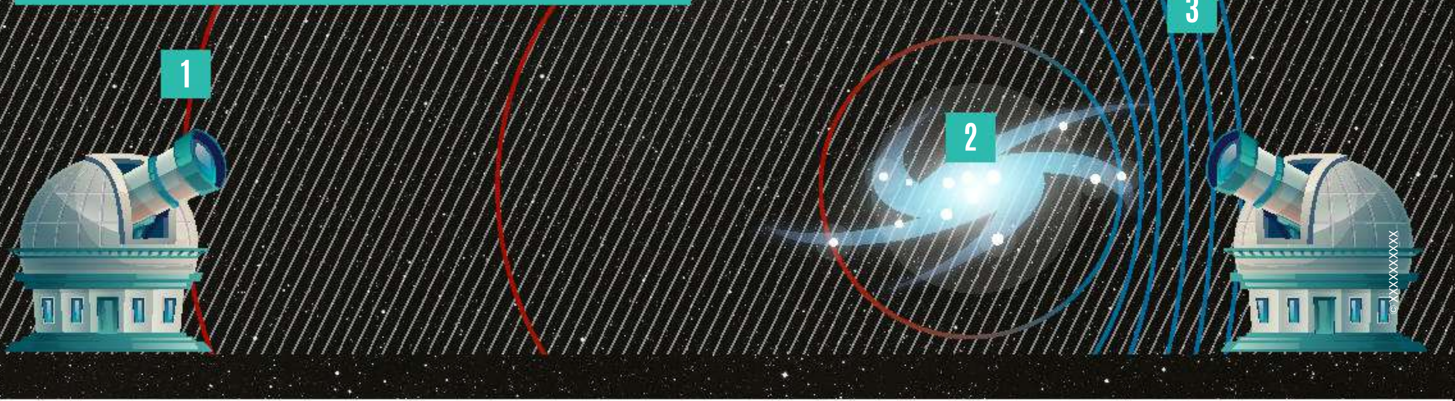
A galaxy far, far away

1 Redshift
As the galaxy moves away, its light is stretched out and moves to the red end of the spectrum.

2 Moving galaxy
A similar effect happens with a galaxy as it moves towards or away from us.

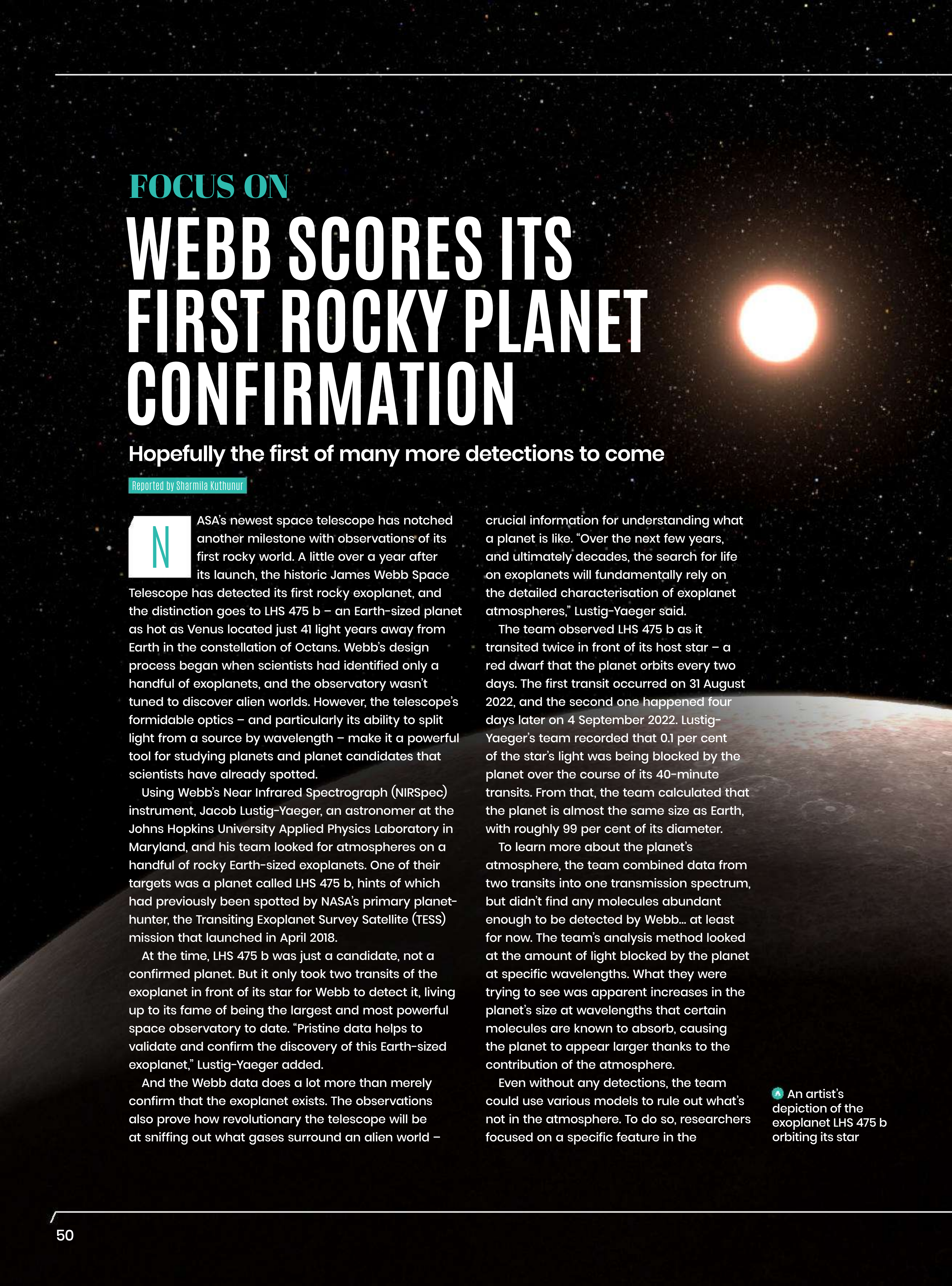
3 Blueshift
As a galaxy moves towards us, its light is compressed and becomes bluer.





XXXXXXXXXX

© NASA/ESA



FOCUS ON

WEBB SCORES ITS FIRST ROCKY PLANET CONFIRMATION

Hopefully the first of many more detections to come

Reported by Sharmila Kuthunur

NASA's newest space telescope has notched another milestone with observations of its first rocky world. A little over a year after its launch, the historic James Webb Space Telescope has detected its first rocky exoplanet, and the distinction goes to LHS 475 b – an Earth-sized planet as hot as Venus located just 41 light years away from Earth in the constellation of Octans. Webb's design process began when scientists had identified only a handful of exoplanets, and the observatory wasn't tuned to discover alien worlds. However, the telescope's formidable optics – and particularly its ability to split light from a source by wavelength – make it a powerful tool for studying planets and planet candidates that scientists have already spotted.

Using Webb's Near Infrared Spectrograph (NIRSpec) instrument, Jacob Lustig-Yaeger, an astronomer at the Johns Hopkins University Applied Physics Laboratory in Maryland, and his team looked for atmospheres on a handful of rocky Earth-sized exoplanets. One of their targets was a planet called LHS 475 b, hints of which had previously been spotted by NASA's primary planet-hunter, the Transiting Exoplanet Survey Satellite (TESS) mission that launched in April 2018.

At the time, LHS 475 b was just a candidate, not a confirmed planet. But it only took two transits of the exoplanet in front of its star for Webb to detect it, living up to its fame of being the largest and most powerful space observatory to date. "Pristine data helps to validate and confirm the discovery of this Earth-sized exoplanet," Lustig-Yaeger added.

And the Webb data does a lot more than merely confirm that the exoplanet exists. The observations also prove how revolutionary the telescope will be at sniffing out what gases surround an alien world – crucial information for understanding what a planet is like. "Over the next few years, and ultimately decades, the search for life on exoplanets will fundamentally rely on the detailed characterisation of exoplanet atmospheres," Lustig-Yaeger said.

The team observed LHS 475 b as it transited twice in front of its host star – a red dwarf that the planet orbits every two days. The first transit occurred on 31 August 2022, and the second one happened four days later on 4 September 2022. Lustig-Yaeger's team recorded that 0.1 per cent of the star's light was being blocked by the planet over the course of its 40-minute transits. From that, the team calculated that the planet is almost the same size as Earth, with roughly 99 per cent of its diameter.

To learn more about the planet's atmosphere, the team combined data from two transits into one transmission spectrum, but didn't find any molecules abundant enough to be detected by Webb… at least for now. The team's analysis method looked at the amount of light blocked by the planet at specific wavelengths. What they were trying to see was apparent increases in the planet's size at wavelengths that certain molecules are known to absorb, causing the planet to appear larger thanks to the contribution of the atmosphere.

Even without any detections, the team could use various models to rule out what's not in the atmosphere. To do so, researchers focused on a specific feature in the

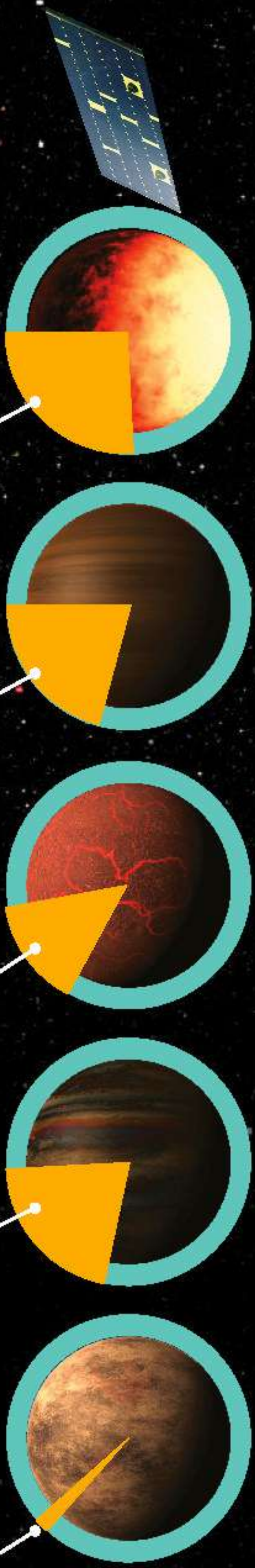
An artist's depiction of the exoplanet LHS 475 b orbiting its star transmission spectrum – a chart depicting how much light is blocked at each wavelength. A transmission spectrum can shed light on important information about a planet. For example, researchers determined that LHS 475 b cannot have an atmosphere dominated by hydrogen like the atmospheres of the gas giants in our Solar System. They also found that a methane-rich atmosphere like the one harboured by Saturn's strange moon Titan isn't likely because methane molecules are expected to block more starlight at certain wavelengths than the researchers observed.

The researchers also modelled a couple of possible atmospheres for LHS 475 b that the Webb data couldn't rule out. On one hand, certain features in the transmission spectrum could be produced by a thin atmosphere consisting of carbon dioxide. On the other hand, the planet could also sport an atmosphere rich in carbon dioxide, much like the atmosphere of Venus.

Such an atmosphere would produce a very flat, featureless spectrum, similar to what "we would expect for a planet that doesn't possess an atmosphere," Lustig-Yaeger said, which provides an excellent fit to the observations as well. It could also explain why the planet appears to be a few hundred degrees warmer than Earth. Given these possibilities, LHS 475 b "could be an airless body that has lost any atmosphere that we are not sensitive to."

EXOPLANETS IN THE UNIVERSE

Some are much more common than others



Hot Super-Earths

Up to 2.5 times the radius of Earth, these orbit much closer to their star, and so have lost most of their early atmosphere.

25.8%

Hot Neptunes

Hot Neptunes have a rocky core and are up to 50 times the mass of Earth, but also have a thick atmosphere of hydrogen and helium.

20.6%

Hot Earths

Roughly the same size as Earth, but because they are in the hot zone, liquid water isn't present on the exoplanet's surface.

16.0%

Hot Jupiters

Once thought unlikely, it now seems that more than 65 per cent of Jupiter-sized planets form in their star's hot zone.

21.1%

Warm Super-Earths

Planets in the habitable zone only account for about 1.4 per cent of those discovered so far, and the majority of them are larger than our home planet.

0.8%

TEN NASA INVENTIONS IN YOUR HOME

Bound by its motto – 'for the benefit of all' – since its formation NASA has had an obligation to foster and transfer its technological and scientific breakthroughs to the public and commercial spheres

1 Crash helmets
Spin-off from 1966 research into impact-absorption foam.

2 Cordless tools
Invented in 1965 to help astronauts collect lunar samples.

3 Personal computers
Made possible thanks to NASA's adoption of the tech during the Apollo program.

4 Scratch-proof sunglasses
A spin-off technology that emanates from astronaut visor protective coatings.

5 Water filters
Designed in the mid-1960s to keep water on board spacecraft pollutant-free.

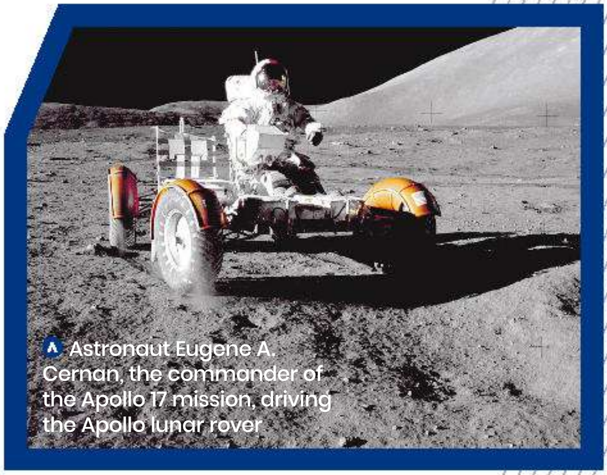
6 GPS myth buster
While GPS technology is commonly credited to NASA, it didn't actually invent it.

7 Modern golf balls
They exist thanks to NASA's research into drag-resistant surfaces in 1981.

Many tools, machines and facilities within your home have their origins in research undertaken by NASA over the past 50 years. Technology originally designed to aid space exploration and land a human on the Moon – an endeavour instigated by US President John F. Kennedy in 1961, where he announced a series of exciting new missions including the groundbreaking Apollo program, as well as numerous research projects – has been successfully and creatively spun off to create some of the staple day-to-day products we now take for granted. From golf balls to gamepads and computers to crash helmets, NASA's technology has been picked up and adapted by specialist companies who have brought

it into the public commercial sphere, delivering new and revolutionary products that have transformed how people live their lives and interact with their environment.

Throughout these pages, **All About Space** delves deep into the NASA archives to discover the innovative research and inventions that made ten of the most common everyday household products possible.


Astronaut Eugene A. Cernan, the commander of the Apollo 17 mission, driving the Apollo lunar rover

JOYSTICKS

Spin-off from: Apollo lunar lander

Mission: Apollo 15 to 17 Date: 1971 to 1972

As with smoke detectors, joysticks already existed before NASA picked up the technology, but they were unrecognisable to the products we see today. Indeed, it was only through NASA's work on joystick technology as a control mechanism for its Apollo lunar rover, which would be used in the last three Apollo missions to the Moon, that we have the digital joystick and thumbstick technology we see in cars, planes and video game control pads. The lunar rover's controller was a T-shaped joystick and worked through a series of motors – four for drive and two for steering. Moving the stick forward powered the rover forward, left and right turned the vehicle left or right and pulling backwards activated the brakes. Activating a switch on the joystick before pulling back would put the lunar rover into reverse, while pulling the handle all the way back activated a parking brake.

WATER FILTERS

Spin-off from: Spacecraft filtration

Mission: Apollo program
Date: 1963 to 1972

Although basic water filters had existed since the mid-1950s, it wasn't until NASA pumped resources into its research for the Apollo program in 1963 that modern filtration systems began to emerge. NASA led research into this area as large quantities of water would need to be kept uncontaminated for long periods of time in extreme conditions.

To achieve this goal, NASA developed a system that worked by utilising charcoal's ability to absorb pollutants and particulate matter present within water when specially treated. This treatment – essentially an oxidisation process that opens up millions of tiny pores between carbon atoms in the charcoal – amplified the absorbability of the charcoal, which with its large, porous surface area provided many sites for pollutants to chemically bond with it through attraction. This left the resultant water clear of impurities.

MICROPROCESSORS

Spin-off from: Integrated circuits

Mission: Apollo program Date: 1963 to 1972

NASA technically didn't invent the integrated circuit, credited to electrical engineer Jack Kilby in 1958, but instead invented newer and more advanced variants of it. Indeed, it's easily argued that NASA's Apollo program kick-started the microchip revolution, with the administration buying more than 60 per cent of America's integrated circuits throughout the whole of the 1960s, deliberately allowing the industry to acclimatise itself to mass production and stabilising it while few other markets existed. One of the first high-profile usages of microchip technology was in the Apollo Guidance Computer with its DSKY interface, which was used to provide onboard computation and control for navigation, as well as control over the Command Module and Lunar Module.

Today, integrated circuits can be found in almost every area of life, from mobile phones and personal computers to microwaves and calculators, mainly thanks to the cheap processing and manufacture of microchips worldwide.

CRASH HELMETS

Spin-off from: Impact-absorbing foam

Mission: Apollo program **Date:** 1966

In 1966 NASA invented temper foam, a shock-absorbing material designed to improve the safety of aircraft cushions. The foam was fitted to the helmets and seats of its Apollo spacecraft, a lining that would help mitigate some of the extreme forces astronauts would be subjected to. Temper foam is a polyurethane treated with additional chemicals that has both high viscosity and density, properties ideal for absorbing large impacts and resisting energy flow. The foam is viscoelastic and temperature sensitive, meaning that when pressed against a heat source, such as a human. it moulds to that shape, aiding fit and reducing unwanted gaps.

Temper foam was released into the public sphere in the early 1980s, soon being picked up and utilised in medical equipment such as temper foam mattresses and sports equipment such as American football helmets and cycle helmets.

SCRATCH-RESISTANT PROTECTIVE LENSES

Spin-off from: Scratch-resistant spacesuit visors and scratch-proof glass and plastic coatings

Mission: Apollo program

Date: 1963 to 1972

Ⓐ An astronaut using a digital camera to expose a photo of his helmet's visor while performing space station maintenance

After NASA realised that plastics were a lot better at absorbing ultraviolet light and didn't shatter if dropped, space visors were produced using plastic. However, uncoated plastic easily scratched, and considering the amount of dust and rubble in a space environment, it was determined scratch-proof lenses and coatings needed to be developed. Due to NASA's research, space visors are now coated with diamond-like carbon coatings that are applied in thin films to the outside of the visor and toughen it massively. An offshoot of this technology is now available on Ray-Ban sunglasses, while Foster Grant historically bought the licence to replicate early coatings to apply to its entire range.

CORDLESS TOOLS

Spin-off from: Cordless zero-impact wrench

Mission: Project Gemini, Apollo program **Date:** 1965

After Kennedy announced the Apollo program in 1961, a deluge of research commenced into the practicalities of human spaceflight. One of the most notable breakthroughs was NASA's collaborative invention with tool company Black+Decker into a cordless zero-impact wrench, a tool that could spin bolts in zero gravity without spinning the astronaut. From this, the research program developed cordless tools for a variety of purposes, including a cordless rotary hammer drill that could be used for extracting rock from the Moon's surface.

These tools worked by exploiting the emerging technology of small-scale rechargeable electrochemical cells that could be grouped to form a battery pack capable of delivering enough power to generate the requisite amount of torque necessary to bore into the Moon's surface crust. Today this technology has become common and widespread, with the majority of tools operating off a cordless battery pack that can be recharged between uses. Interestingly, it was directly from the research done by NASA in the 1960s that Black+Decker developed the cordless 'Dust Buster' handheld vacuum cleaner.

SATELLITE TELEVISION

Spin-off from: Satellite communication
Mission: Telstar
Date: 1962

The first satellite capable of relaying TV signals was Telstar 1. Launched in 1962, it was a joint project to develop an experimental satellite communications system over the Atlantic Ocean. The satellite was built by Bell Laboratories in partnership with NASA. The satellite worked by utilising a transponder to relay data. It received microwave signals through an omni-directional array of small antennae before upscaling and amplifying the signal's frequency in a travelling-wave tube and retransmitting to the ground.

NASA continued to develop this technology, producing more advanced systems to reduce noise and errors in transmitted signals, leading to the ability to transmit high-definition video and audio.

SHOE INSOLES

Spin-off from: Lunar boots
Mission: Apollo program **Date:** 1963 to 1972

One of the most notable inventions NASA included in its spacesuits was its special 3D 'spacer' material in the boots for cushioning and ventilation. Used to give astronauts better control, agility and longevity while on their feet, the lunar boot was an overshoe that slipped on over the integral pressure boot of the spacesuit.

The outer layer was made from metal-woven fabric, except for the ribbed silicone rubber sole that provided extra springiness and comfort while moonwalking. The tongue area was made from Teflon-coated glass-fibre cloth, while the inner layers were made from this, followed by 25 alternating layers of Kapton film to form an efficient, lightweight thermal insulation.

From this, shoe manufactures created a series of lightweight, warm and springy running shoes and trainers that are now on sale worldwide in high-street shops.

A bootprint on the Moon from NASA's Apollo 11 mission. NASA added springy soles and a ventilation system to spacesuit boots for the Apollo program

"Mr… Spock… I… have… a plan"

MODERN GOLF BALL DIMPLES

Spin-off from: Drag-resistant surfaces
Mission: Space Shuttle
Date: 1981

Wilson
DISTANCE
ProStaff
4

As part of the Space Shuttle program, NASA undertook research into maximising the drag resistance of its new launch system's surfaces, especially for the external fuel tank.

The special dimpled surface applied to the tank allowed NASA to hit a more optimum lift-to-drag ratio, getting more distance and stability out of its launch. After being released into the public sphere, this aerodynamic coating was studied by the Wilson Sporting Goods Company. Its engineers learned that by applying dimples to the surface of a golf ball, the ball could glide more smoothly with less aerodynamic drag. With 3D computer graphic software, the Wilson engineers were able to predict the progress made for the new golf ball and designed one with medium-sized dimples that created both high lift and far-gliding potential. Today, all golf balls utilise this dimpled coating.

The Saturn V launch, the carrier for Skylab

HOUSEHOLD SMOKE DETECTOR

Spin-off from: Adjustable smoke detector
Mission: Skylab **Date:** 1973

The smoke detector, while invented by Francis Robbins Upton in 1890, wasn't adjustable until NASA invented a model with variable sensitivity in 1973. The units were installed on Skylab to detect toxic vapours on board. They worked through ionisation, a process that involves using a small quantity of the radioactive isotope americium-241 to ionise oxygen and nitrogen atoms in a detector's embedded air chamber, which itself is topped and bottomed with two metal plates attached to the battery. While ionisation occurs, the freed electrons are attracted to the plate with a positive voltage plate and the electron-less atoms to the negative voltage plate, creating an electric current.

When smoke particles from a fire enter the air chamber, they disrupt the current as they attach to the ions and neutralise them. The smoke detector senses the drop in current and sets off the alarm.

©NASA

NOT FROM NASA

TANG

This tasty beverage was developed by General Foods in 1957. Tang rose to prominence after it was selected for a NASA mission's menu in 1962.

VELCRO

Used by NASA to anchor equipment in zero gravity for the convenience of astronauts, Velcro was not invented for Apollo. Contrarily, it was a Swiss invention of the 1940s.

TEFLON

Teflon was invented as far back as 1938 by the science company DuPont. NASA's relationship with the material extends to it being used in heat shields, spacesuits and cargo hold liners.

BARCODES

NASA did invent a special variant of the barcode to be used to log and categorise the inventory of the Space Shuttle.

QUARTZ CLOCK

This piece of technology is often credited to NASA due to a joint project run in the 1960s to create a highly accurate quartz timepiece. In fact, the quartz clock was invented in 1927 by Joseph W. Horton and Warren A. Marrison.

INSTANT EXPERT

HOW HIGH COULD WE JUMP ON OTHER WORLDS?

What is low gravity like, and how high could we leap on alien surfaces?

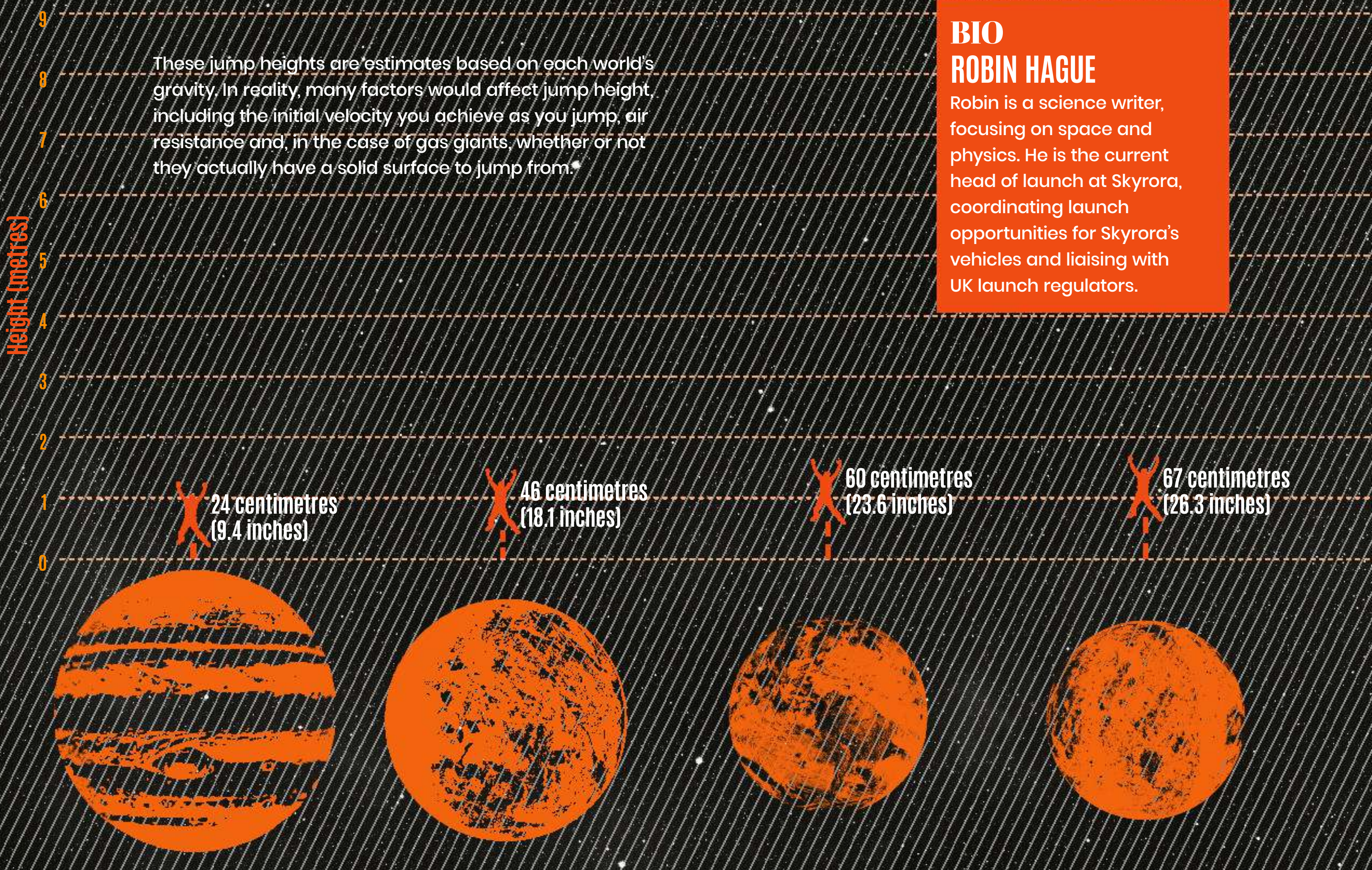
When watching footage of the Apollo astronauts exploring the lunar surface, possibly the most striking thing is how they move in the lower lunar gravity. We're quite used to seeing people working in microgravity conditions, whether on the International Space Station or experimental aeroplanes, but only 12 people have ever properly felt that curious low gravity of the Moon.

Gravity is the force that occurs between any objects with mass. The Moon has one-sixth the gravity of Earth because it has only one-sixth the mass of our planet. With less gravity, we get a combination of effects Friction between surfaces, like between your shoes and the ground, depends on

These jump heights are estimates based on each world's gravity. In reality, many factors would affect jump height, including the initial velocity you achieve as you jump, air resistance and, in the case of gas giants, whether or not they actually have a solid surface to jump from.

BIO
ROBIN HAGUE

Robin is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.



Jupiter
Surface gravity: 2.5 g
If you could stand on Jupiter, it would be hard to jump at all. At more than double Earth's gravity, just lying down would feel like a Space Shuttle launch.

Kepler-442b
Surface gravity: 1.3 g
This habitable exoplanet is over 1,000 light years away. It is about 33 per cent larger than Earth and over double its mass, so jumping would be a struggle.

Earth
Surface gravity: 1.0 g
60 centimetres (23.6 inches) is a reasonably average jump on our home planet without going into the high jump techniques used by athletes.

Venus
Surface gravity: 0.9 g
The hellish ground conditions of Venus mean that if any jumping ever happens, it will have to be in balloon cities in the upper atmosphere.

the force pushing the surfaces together, so less gravity means slippery shoes. This tendency to slip, and the physical restrictions of spacesuits, led the Apollo astronauts to develop their characteristic skip, which showed off the low gravity by how high they were skipping. So, given a suitable lunar base with enough room, how high could you jump on the Moon?

Everyone jumps differently, of course, but anywhere around 60 centimetres (23.6 inches) is an average jump on Earth without getting into high jump techniques. Leap height depends on how fast your body can push you upwards, and for the same set of legs on different planets, that depends on how strong gravity is.

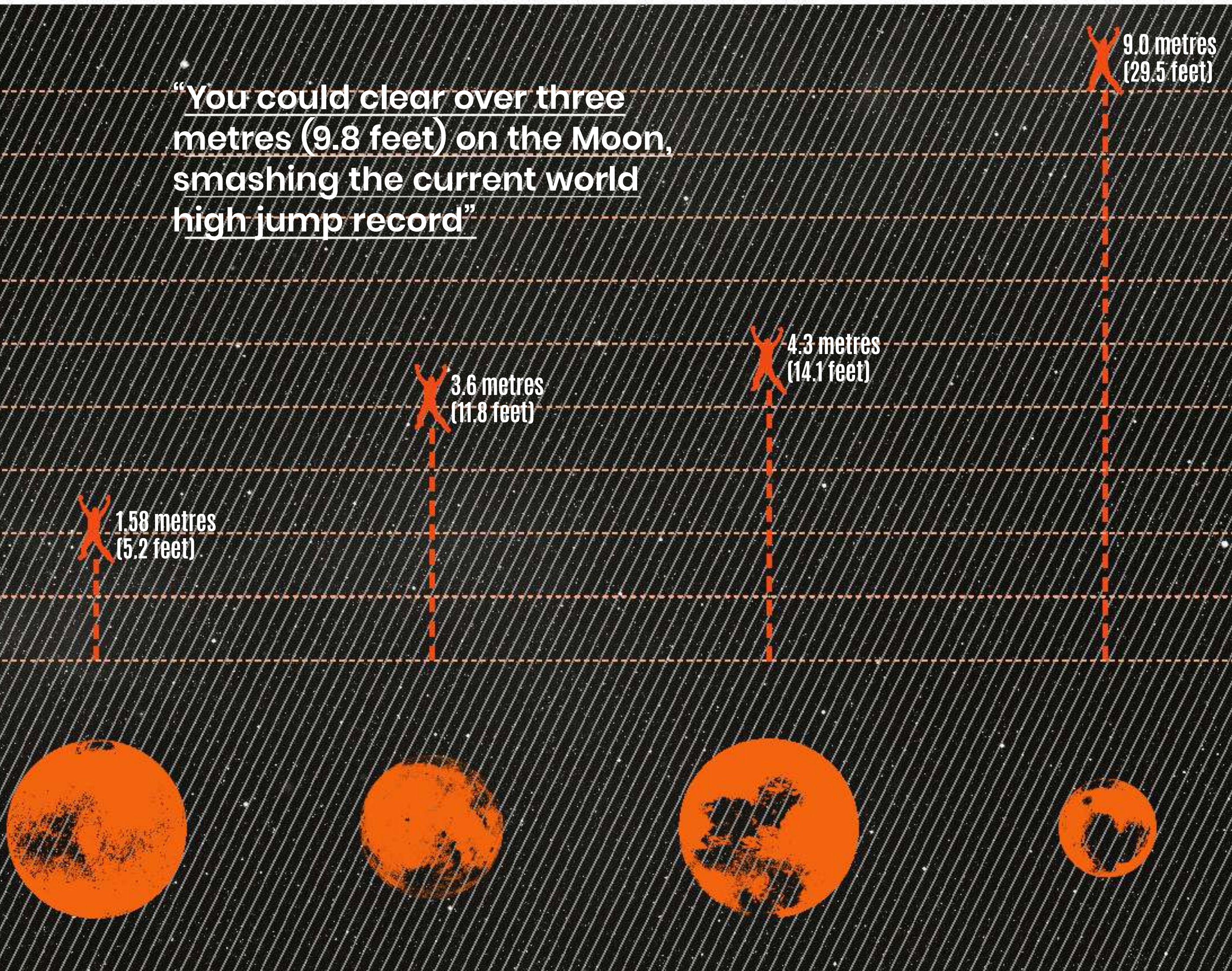
On the Moon, you'd be able to jump six times higher than you can right now – if you can manage 60 centimetres (23.6 inches) on Earth, then you could clear over three metres (9.8 feet) on the Moon, smashing the current world high jump record.

The next likely destination for humans is Mars. The Red Planet is also smaller than Earth, with one-third the gravity, so you would be able to jump nearly three times as high, which is nearly the height of a standard door.

Within our Solar System, the most Earth-like gravity should be Venus, with a surface gravity 90 per cent that of Earth's, allowing you to jump 67 centimetres (26.3 inches), but we're unlikely to ever build a base or spacesuit that could allow us to stand on the surface of Venus due to the 400 degree Celsius (752 degree Fahrenheit) temperature and an atmospheric pressure 92 times that on our planet. If we do reach Venus, you'll have to do your jumping in surprisingly feasible balloon-supported bases floating 50 kilometres (31 miles) above the surface.

Even though it's made up of gas, Jupiter has a much higher mass than Earth. But the absence of a ground surface on gas giants such as Jupiter and Saturn means gravity varies greatly throughout the planet. The mass of Jupiter is 318 times that of Earth's, suggesting that if you did manage to find a floor you would probably be squashed flat due to atmospheric pressure.

> **"You could clear over three metres (9.8 feet) on the Moon, smashing the current world high jump record"**



Mars
Surface gravity: 0.379 g
Both the Moon and Mars are likely to offer the planetary bases necessary to actually try this sometime during this century.

The Moon
Surface gravity: 0.165 g
The Apollo astronauts were severely restricted by their spacesuits, but they still managed some impressively high hops.

Titan
Surface gravity: 0.138 g
The only other surface in the Solar System where pressurised clothing isn't needed, but may have huge, slow-motion, low-gravity methane raindrops.

Pluto
Surface gravity: 0.063 g
Smaller than our Moon, on Pluto you could get a view like New Horizon's with unbelievably high nine-metre (29.5-foot) jumps.

© NASA

MYSTERIES OF THE UNIVERSE

HOW DID SOME STARS BECOME LOST SOULS?

Scientists have been studying a ghostly light in between galaxies to discover the origin of these unusual stellar objects

Reported by David Crookes

In 1951, Swiss astronomer Fritz Zwicky was observing the Coma Cluster of galaxies using a telescope at Palomar Observatory in San Diego County, California. This cluster, containing more than 1,000 identified galaxies, is located in the constellation of Coma Berenices, and it's known to be one of the densest in the universe. While looking at the Coma Cluster, Zwicky noticed there was light in the region between the galaxies. Although the glow was faint, this luminescent intergalactic matter nevertheless pointed to the presence of stars. The difference is, these stars were rogue. Since they were outside of the galaxies, they were considered homeless. Their fate, it would seem, was to wander endlessly in the vastness of space. But how did they get there?

The presence of such stars has been a mystery ever since, and while astronomers have come up with a number of theories to explain how these stars came to be gravitationally untethered from any single galaxy, none have been entirely satisfactory. In fact, as a recent study suggests, previous explanations for how these lost souls ended up being scattered across clusters are now being thrown to the wind. Even with fresh light having been cast on the mystery, it remains unresolved, although we are admittedly getting ever closer.

Among those to take a keen interest in the presence of light between the galaxies is Professor Myungkook James Jee from the Department of Astronomy at Yonsei University in Seoul, South Korea. He has been part of a groundbreaking study that has sought to better explain what is known as intracluster light. This has particularly focused on ten galactic clusters located as far as 10 billion light years away, and

© Getty Images

INTRACLUSTER LIGHT BY NUMBERS

TEN

Number of galaxy clusters studied in a recent survey

7.7 BILLION

Minimum distance of those galaxy clusters in light years

1/10,000TH

Intracluster light from these clusters is 1/10,000th the glow of the night sky as seen from Earth-based telescopes

10 BILLION

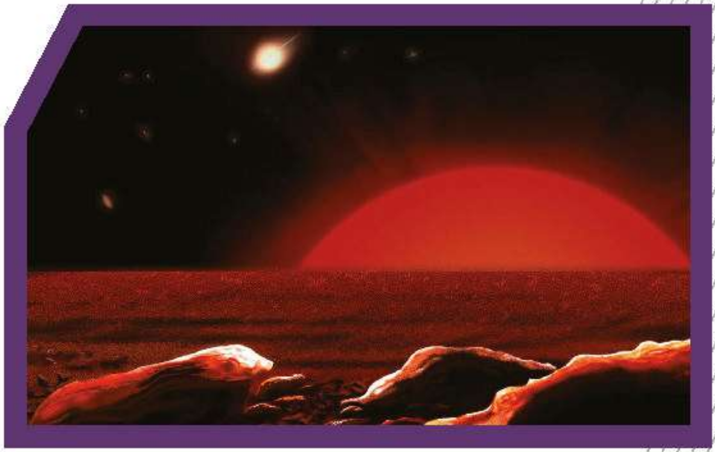
Maximum distance of those galaxy clusters in light years

330 MILLION

Distance in light years to the Coma Cluster, where intracluster light was discovered in 1951

300,000

Distance in light years of orphan stars from the nearest big galaxy in the Virgo Cluster of galaxies



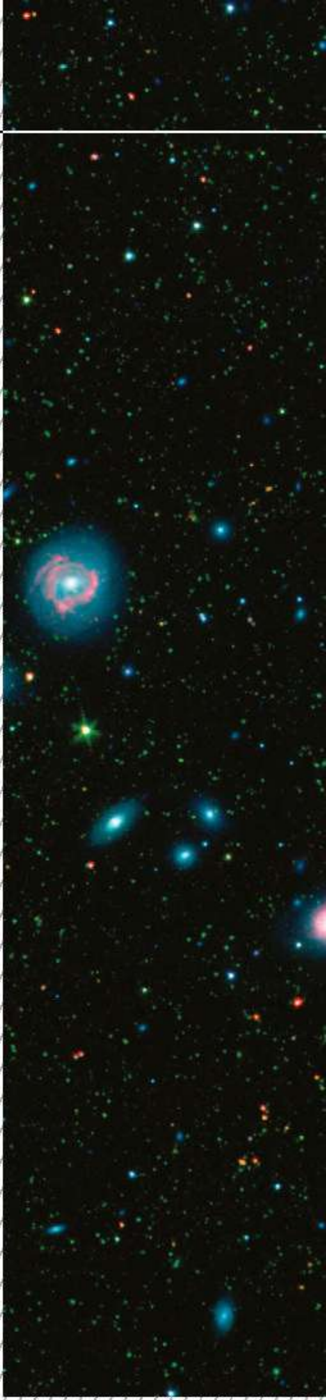
> "Since intracluster stars aren't bound to individual galaxies but to the cluster, they can serve as visible tracers of dark matter" **Myungkook James Jee**

the findings have been startling. "My expertise is gravitational lensing, and I am interested in accurately mapping dark matter distributions in galaxy clusters with it," Jee explains to **All About Space**. "Although gravitational lensing is a powerful tool to make the invisible visible, I always wanted to find an alternative way to trace dark matter.

"Since intracluster stars aren't bound to individual galaxies but to the cluster, they can serve as visible tracers of dark matter. This is how I became interested in intracluster stars. I published my first intracluster light paper in 2010 to trace the ring-like dark matter structure in the galaxy cluster CL0024+17 that I reported with weak gravitational lensing in 2007. Since then my interest has expanded, and I'm also interested in the origin of the intracluster stars."

The study, which has been published in the journal *Nature*, has made use of an infrared survey by the Hubble Space Telescope, highlighting that the famous observer is still more than capable of making new discoveries more than 32 years after being launched into low-Earth orbit. It's a huge jump from the relatively tiny telescope used by Zwicky – and it comes 25 years after Hubble found stellar outcasts in the Virgo Cluster of galaxies 60 million light years away – but it's position in space has meant that it's been able to detect faint intracluster light that's some 10,000 times dimmer than the night sky as seen from Earth.

"Intracluster light is very, very faint," Jee explains. "In particular, it's extremely difficult to observe the intracluster light in the distant universe because it can only be seen in the infrared. Earth's infrared sky isn't so dark, thus we need to use the Hubble Space Telescope. In space, the infrared sky is much darker." As a result, visibility has been much improved, allowing the scientists to better measure the amount of light in the ten galactic clusters that were being observed.



Astronomer Fritz Zwicky discovered intracluster light in the Coma Cluster in 1951

An artist's impression of the view from an orphan intracluster star in the Virgo Cluster of galaxies

Scientists will discover more about intracluster light and stars thanks to the James Webb Space Telescope's ability to accurately access near-infrared wavelengths

© NASA; Los Alamos National Laboratory;

THREE POTENTIAL EXPLANATIONS

Scientists have long considered the origin of intracluster stars

The stars have been stripped

The movement of a galaxy through the intracluster medium can cause material to be pushed out of a galaxy. But if this were the case, it would cause an increase in intracluster light over time. This isn't happening. The amount of light is remaining the same, so stripping isn't the primary mechanism and recent ejection can be ruled out.

Stars were thrown out following mergers

A galactic merger can also cause stars to be displaced. This could potentially force them to move outside of a galaxy and become orphaned. However, this takes time, and there has been insufficient time for the stars to have become scattered across the whole cluster in the manner that has been observed, making this unlikely.

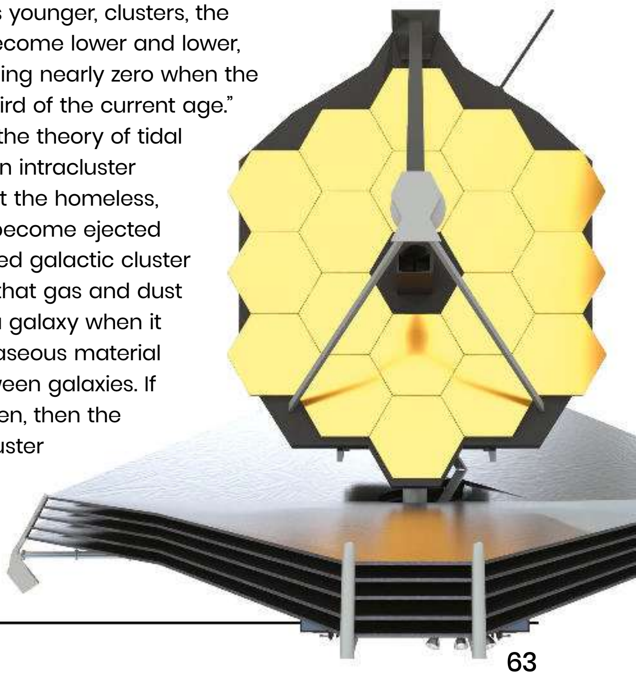
They formed billions of years ago

The results of the recent survey by Hubble indicate that the origin of the intracluster stars is older than previously thought and that they have been around for billions of years. Did they form and grow alongside the galaxies or were they simply strays from the start? More work is being carried out to resolve the mystery.

Before embarking on the study, astronomers believed that stripping best explained how the stars ended up being scattered and gravitationally bound to the halo of galaxy clusters rather than individual member galaxies. “The leading theory has it that the intracluster stars were mostly produced by stripping in the recent universe,” says Jee, of a process in which material is pulled out of galaxies by massive gravitational tides.

He goes on to explain exactly what this would entail. “When a galaxy gravitationally interacts with another galaxy or the cluster, it loses some of its stars because of the tidal force – an event astronomers call tidal stripping,” he says. “Thus the leading theory regarding the origin of intracluster light has been that a majority of intracluster stars had been produced in this way. But if this is the dominant production mechanism then it's expected that the intracluster light fraction – the ratio of the unbound star luminosity to the total luminosity – increases with time. That is, as we look at more and more distant, thus younger, clusters, the fraction should become lower and lower, eventually becoming nearly zero when the universe is one-third of the current age.”

In other words, the theory of tidal stripping to explain intracluster light suggests that the homeless, wandering stars become ejected from an established galactic cluster in the same way that gas and dust is pushed out of a galaxy when it moves through gaseous material in the space between galaxies. If this were to happen, then the fraction of intracluster light would increase as the years roll by because more



stars would be stripped and forced to become lone souls. "According to the leading theory, there should be very little or no intracluster light in the distant universe because the intracluster stars were produced only recently," Jee says. Yet the study showed this hadn't happened. "The survey revealed that intracluster light is already abundant in the distant universe when the universe is one-third of the current age. This implies that its origin is much older than thought."

Indeed, the Hubble Space Telescope's survey clearly showed that the ratio of intracluster light compared to the total light of the clusters has changed very little over the last 10 billion years, so the stars were already homeless in the early stages of the cluster's formation. "Our observation reveals that the intracluster light fraction is in fact as high as 17 per cent in the distant universe, which is nearly the same as the one in today's universe," Jee says. "This proves that the classical stripping theory cannot be right. Of course, we believe that stripping plays some role in the production of intracluster stars, but it cannot be the dominant mechanism. As we revealed in our *Nature* paper, the intracluster light fraction becomes really small at a redshift of 1.6. On the other hand, our observation shows that the actual intracluster light fraction is much higher than the theory."

Even so, while this goes a long way towards pointing out why stripping isn't the correct explanation for the reason some stars end up wandering among the galaxies, no new theory truly nails down an answer to the mystery… at least not yet. But there's evidence that these stars were produced in large quantities in the early universe. "In their early formative years, galaxies might have been pretty small, and they bled stars pretty easily because of a weaker gravitational grasp," says Jee. But scientists are continuing to work on an explanation. "This is the topic of our follow-up paper," Jee teases. "According to our state-of-the-art cosmological simulation results, the stars became homeless very early. However, certainly they were not born on the street. Please stay tuned."

While we await that paper, there's also a very high chance that we'll start to discover much more about intracluster light thanks to the advanced nature of the James Webb Space Telescope. At the tail end of 2022 this telescope produced its first deep-field image, and it clearly showed the faint light from the orphan stars despite possessing just one per cent of the brightness of the darkest sky seen over our planet. It's an exciting time for astronomers interested in intracluster light. "With the Hubble Space Telescope, we were able to trace back in time to a redshift when the universe is 25 per cent of its current age. We hope Webb can enable us to reach as far as a redshift of 4.0, when the universe is ten per cent of its current age,' says Jee. "At this early age, we will be able to detect intracluster light from so-called protoclusters, which will get us even closer to its origin." What's more, studies into how galactic clusters form and how stars become orphaned will aid astronomers working on another ongoing mystery: dark matter, an invisible yet important entity that makes up some 27 per cent of the universe.

Dark matter has been confounding and fascinating astronomers for more than 80 years, not least because it's unlike

LOOKING FOR INTRACLUSTER LIGHT

How Hubble has helped scientists learn more about the origin of intracluster stars

1 General clusters

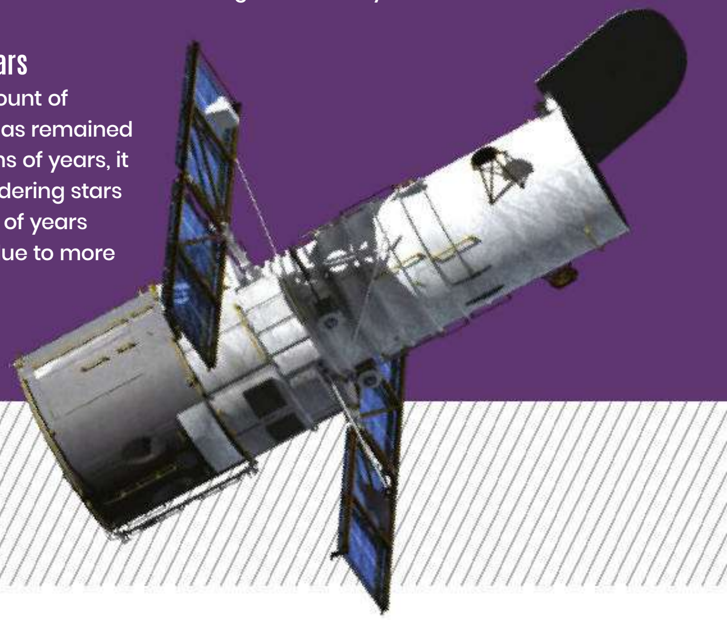
Here we can see two massive galaxy clusters as observed using the Hubble Space Telescope. On the left there is MOO J1014+0038, and on the right there is SPT-CL J2106-5844.

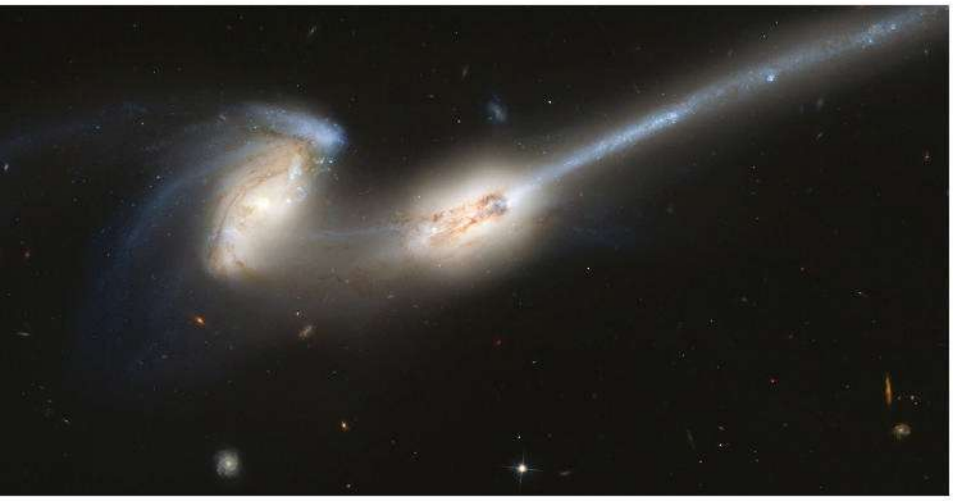
2 The intracluster light

Blue colouring has been added to these images, after studying the data taken from Hubble. This shows the extent of the intracluster light. This ghostly haze is due to gravitationally unbound stars.

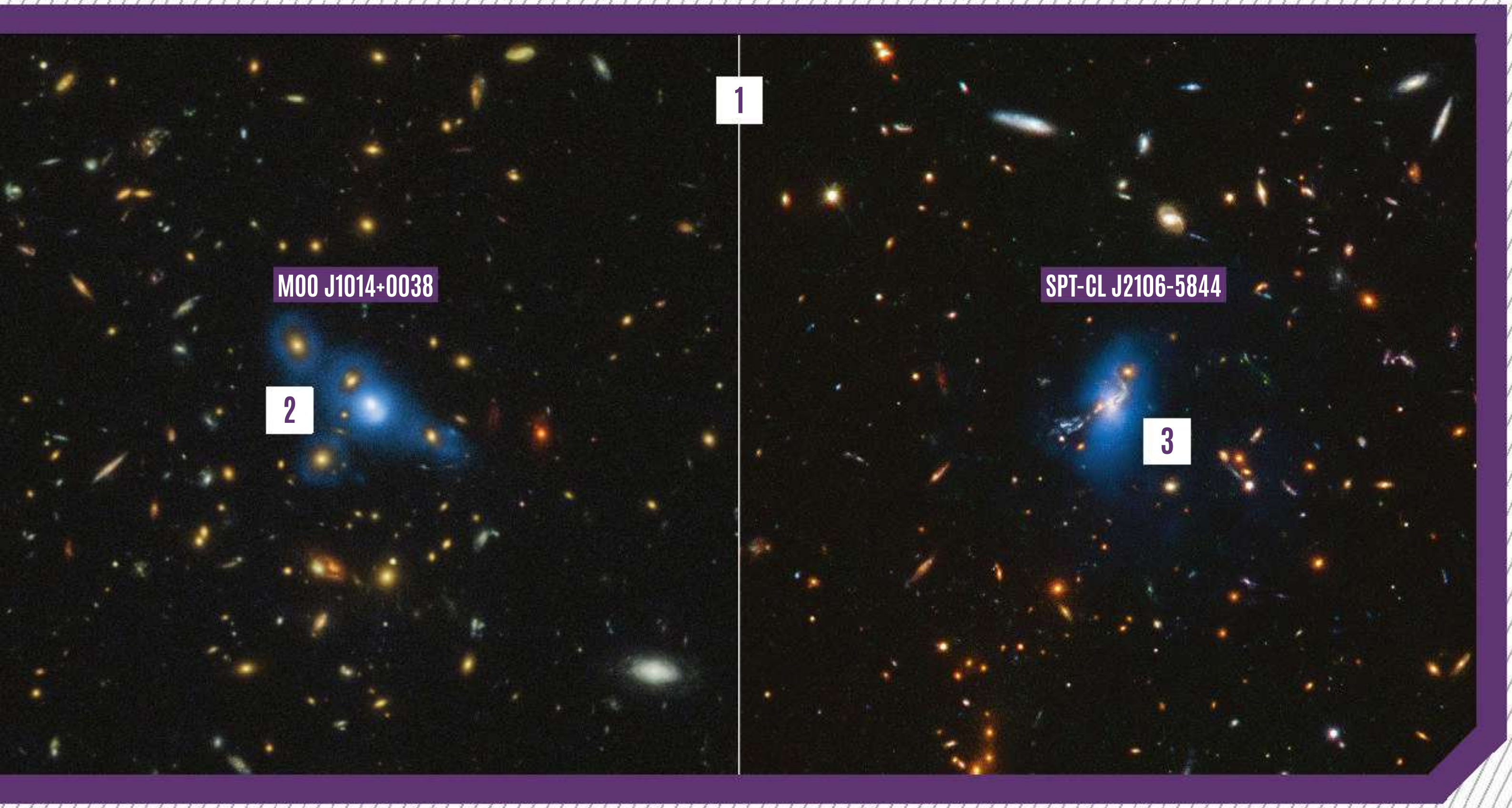
3 Ageing the stars

Since the amount of intracluster light has remained constant for billions of years, it suggests the wandering stars were shed billions of years ago and are not due to more recent activity.





Galaxies which gravitationally interact lose stars because of tidal force – this was once a leading theory for the origin of intracluster stars



© NASA ESA

the normal matter that we find here on Earth. It's not composed of baryons, the 'normal' matter particles which make up the planets, stars and even ourselves. It doesn't emit or absorb light and it cannot be directly observed. About the only thing astronomers can hypothesise with some certainty is that dark matter interacts through gravity. According to the Yonsei University study authors, working out the origin of intracluster stars will go some way towards a better understanding of how an entire galaxy cluster has been assembled over time. In fact, astronomer Hyungjin Joo says intracluster stars can "serve as visible tracers of dark matter enveloping the cluster."

By understanding that intracluster stars were born in a cluster's early years, astronomers know they will have fully dispersed throughout a cluster, the study authors say, and this would help to map dark matter. "We can first separate intracluster stars from the rest of the stars bound to individual galaxies," explains Jee. "Then this intracluster star map can serve as a proxy for the dark matter map." It potentially means that we're going to get ever closer to resolving two ongoing mysteries, with the power of NASA's James Webb Space Telescope once again opening more and more doors for scientists observing the universe. On the one hand, astronomers will discover more about intracluster light, and on the other find out more about dark matter. For now, it's just a case of watching that space.

David Crookes

Science and technology journalist

David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

The James Webb Space Telescope has already taken a deep-field image including intracluster light of the cluster SMACS-J0723.3-7327

> **"We believe stripping plays some role in the production of intracluster stars, but it cannot be the dominant mechanism" Myungkook James Jee**

FOCUS ON

EXCEPTIONALLY RARE BINARY SYSTEM WITH A THOUSAND-YEAR ORBIT

The star Gaia17bpp began brightening again after a seven-year eclipse, indicating it exists in an unusual set-up

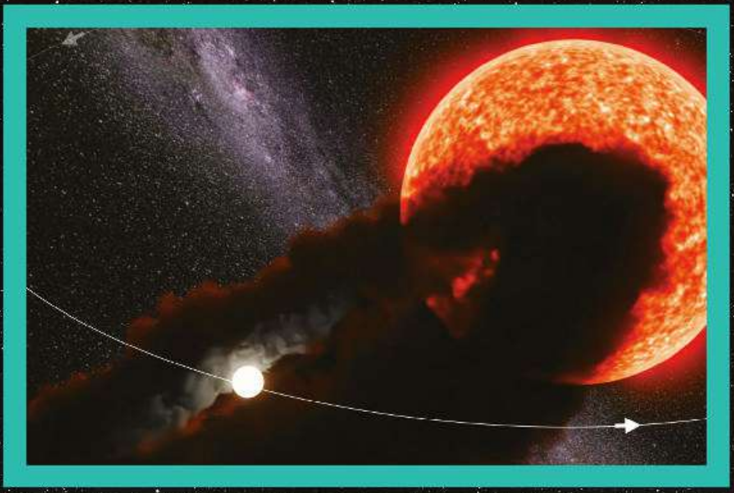
Reported by Robert Lea

The dimming of a distant star wasn't caused by internal changes, but rather by it being eclipsed by a cloud of dust surrounding a companion star. The discovery implies the star, Gaia17bpp, is part of a rare type of binary system, and its recently observed sudden brightening was the result of the eclipse by a white dwarf companion ending. Astronomers made the discovery as they searched through data from the Gaia spacecraft's survey for unusual stars. They found that Gaia17bpp had gradually brightened over a two-and-a-half-year period, with follow-up investigations revealing it had been dimmed for seven years as a result of being obscured by dust surrounding its odd companion.

The discovery was one of exceptional good fortune as the binary system has a long orbital period, meaning it's rare to catch one eclipsing the other. In fact, such events may come just once a millennium. "Based on our analysis, these two stars orbit each other over an exceptionally long period of time – as much as 1,000 years. Catching this bright star being eclipsed by its dusty companion is a once-in-a-lifetime opportunity," said University of Washington astronomer Anastasios Tzanidakis. Gaia's observations of Gaia17bpp only date back to 2014, so along with collaborator James Davenport, an assistant professor at the University of Washington and associate director of the Institute for Data-intensive Research in Astrophysics and Cosmology, Tzanidakis had to do extra investigative legwork to solve the mystery of the star's behaviour.

The first step was to combine Gaia observations with observations from other missions such as Pan-STARRS1, NEOWISE and the Zwicky Transient Facility, which date as far back as 2010. This revealed to Tzanidakis and Davenport that the star had become 63 times or +4.5 magnitudes dimmer over the course of seven years, between 2012 and 2019, and that the rapid brightening of Gaia17bpp marked the end of this period. The astronomers went back further using the Digital Access to a Sky Century (DASCH) program, a digital catalogue of over 100 years of astrophotographic plates stored at Harvard University, to track the star's brightness since the 1950s. They found no similar periods of dimming for Gaia17bpp or other stars in its vicinity.

"Over 66 years of observational history, we found no other signs of significant dimming



An artistic rendering of the star Gaia17bpp being partially eclipsed by the dust cloud surrounding a smaller star in this star," said Tzanidakis. He and Davenport think that Gaia17bpp exists in a rare type of binary system with a dusty companion star. "Based on the data currently available, this star appears to have a slow-moving companion that is surrounded by a large disc of material," Tzanidakis continued. "If that material were in the Solar System, it would extend from the Sun to Earth's orbit, or farther."

The binary containing Gaia17bpp isn't the first dusty system spotted by astronomers. One notable example of such a binary contains Epsilon Aurigae. For two years out of every 27, this star in the constellation of Auriga is eclipsed by its large and dim companion.

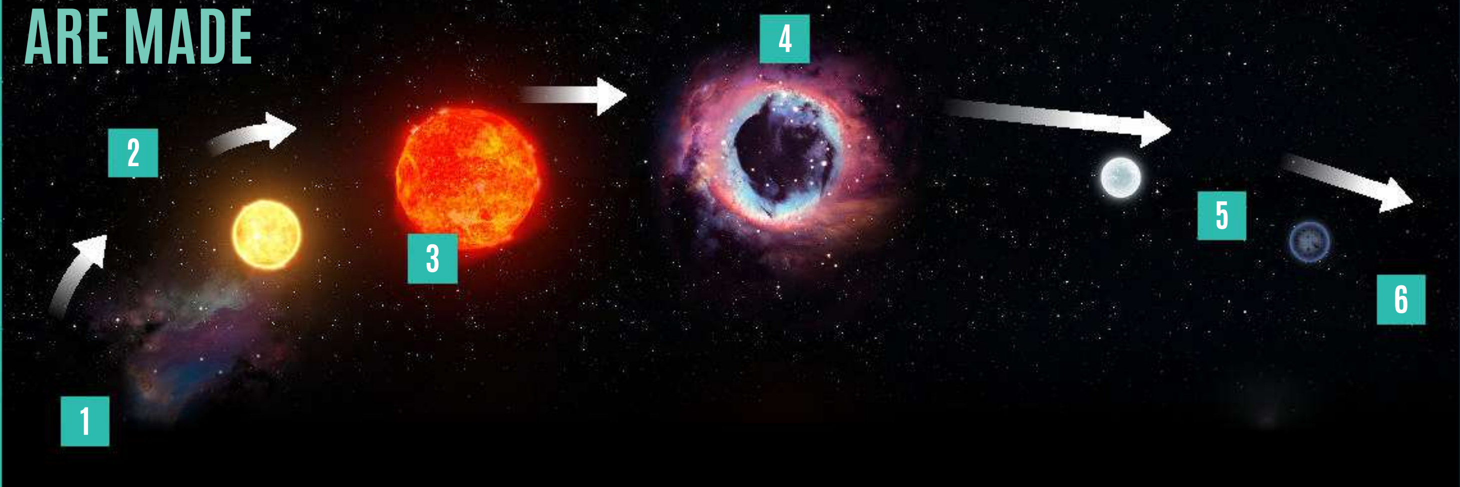
While the companion of Epsilon Aurigae is of a mysterious nature, its identity thus far unconfirmed, preliminary data indicates that the dusty eclipsing companion of Gaia17bpp is a white dwarf, a stellar remnant that is born from the death of stars with masses similar to our Sun.

Though the nature of the companion of Gaia17bpp may be known, the source of the dusty debris which takes a disc-like shape around the white dwarf remains a mystery.

Compared to other dusty binaries, the seven-year dimming of Gaia17bpp indicates what is by far the longest eclipse period. Additionally, the vast distance between Gaia17bpp and its companion means it will be centuries before any other astronomers witness the dusty binary during an eclipse. "This was a serendipitous discovery. If we had been a few years off, we would've missed it," Tzanidakis said. "It also indicates that these types of binaries might be much more common. If so, we need to come up with theories about how this type of pairing even arose."

> "Over 66 years of observational history, we found no other signs of significant dimming in this star" **Anastasios Tzanidakis**

HOW WHITE DWARFS ARE MADE



1 Nebula Giant clouds of dust and hydrogen and helium gases. Clumps of a nebula subjected to the influence of gravity, radiation and temperature form a hot, independent core. This takes 100,000 years.

2 Yellow dwarf An average yellow G-type main-sequence star like our Sun will form, and through nuclear fusion will burn up its central core of hydrogen and helium. Their life span is about 10 billion years.

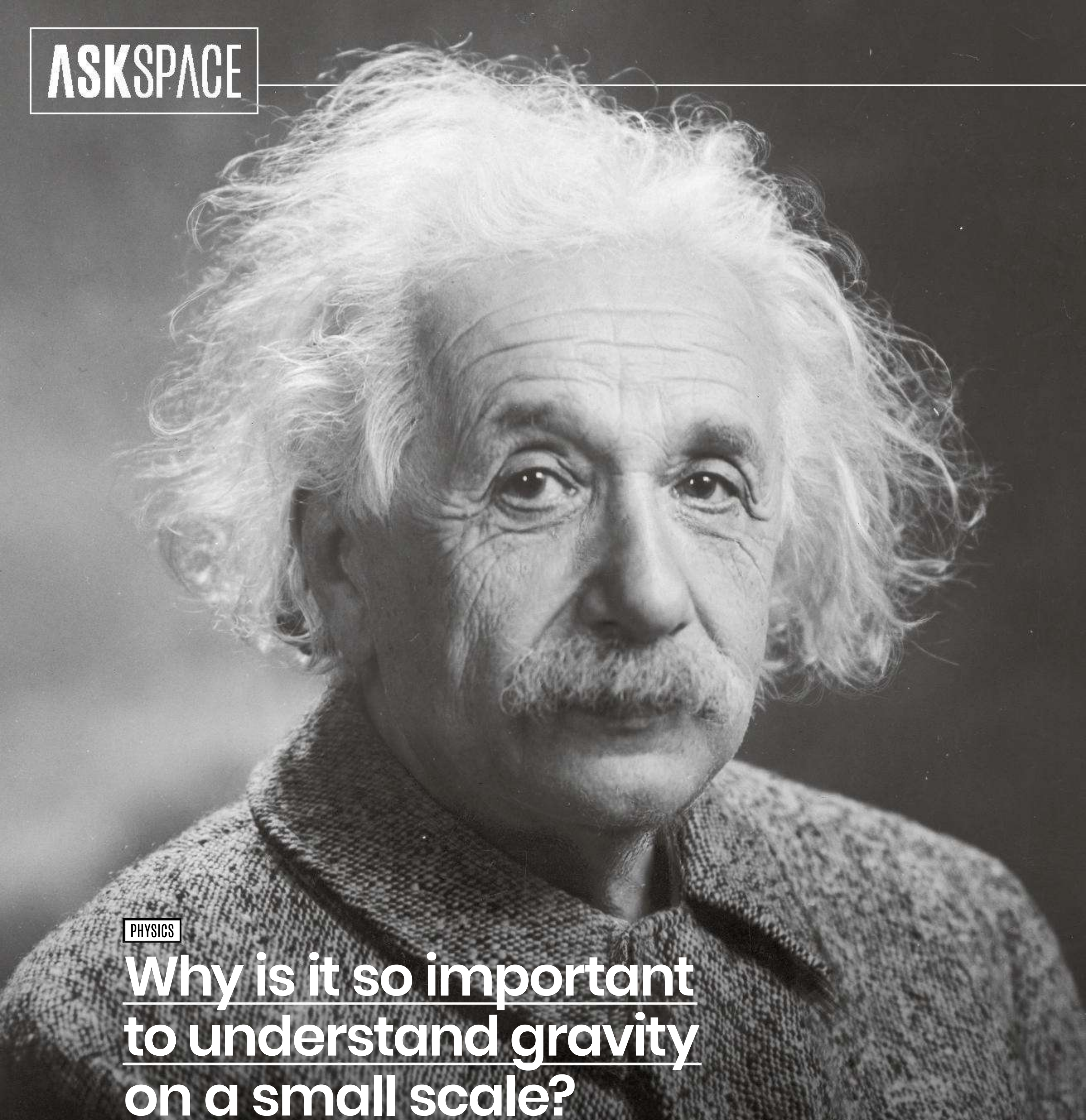
3 Red giant As hydrogen fuel is used up in the core of a star, hydrogen burning occurs outside the core, causing the star to expand. The life of a red giant lasts around 1 billion years.

4 Planetary nebula In the last stages of the life of a red giant, its huge shell of gas and dust – containing nitrogen, neon, oxygen, carbon and helium – is ejected, forming a planetary nebula.

5 White dwarf The remaining core of a red giant, stripped of its outer layers, is now designated a white dwarf. Its volume might be the size of Earth, but it will have a mass equal to our Sun. The core is very hot.

6 Black dwarf It's been calculated that it will take tens or even hundreds of billions of years before a white dwarf will have expended all its energy to become a dim black dwarf.

© Tobias Roetsch; Anastasios Tzanidakis

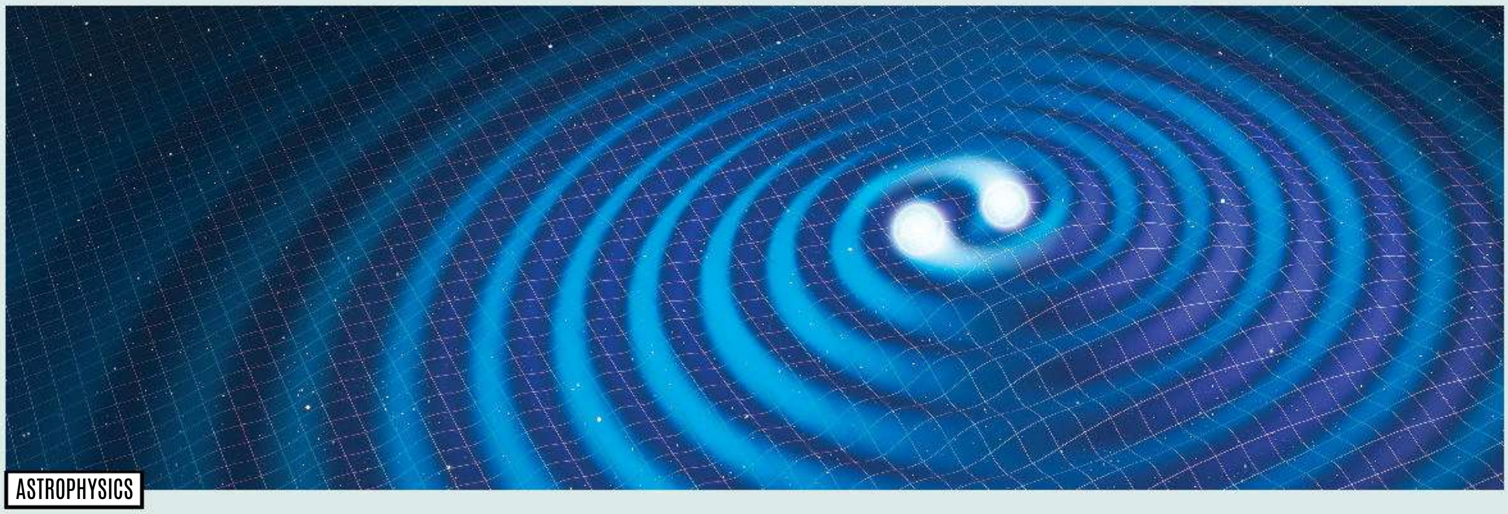


PHYSICS

Why is it so important to understand gravity on a small scale?

That's difficult to answer, because important means different things to different people. I think that there's a human curiosity to understand the world that's surrounding us, and that transcends the scientific community. For me, it's just a very curious thing. However, if importance for you is the impact on your daily life, or something like that, then I think that a better understanding of our world will at some point also have an impact on our daily lives. Einstein, for example, didn't imagine the navigation systems on your phone, but it wouldn't work without his theories. At some point I think it will affect our daily lives, but it's not my main motivation. It's just my curiosity that drives me to understand how gravity works at small scales.

Jeremias Pfaff, PhD student at the University of Vienna studying the boundaries of quantum physics and gravity



▲ Colliding massive objects produce waves detectable from Earth

ASTROPHYSICS

What sort of objects generate gravitational waves?

They're produced by pretty much anything – you, me, cars, planes. But we're tiny, and space is very 'stiff' – it really doesn't like to deform, and so while we do produce gravitational waves, they're minuscule in terms of amplitude. Basically, we're looking for violent things. To get a signal that's strong enough to measure on Earth, or in orbit near Earth, it really has to be a very big, violent event in the universe.

Gravitational waves are created by an acceleration of mass. If you think of two objects orbiting each other, you can have an angular acceleration – if you have two stars orbiting and you're viewing them from a long way away, then at some times you see the two stars separated, with one gravity field, and at other times they're roughly in line with each other. If you think of the electromagnetic spectrum, then you have radio telescopes and X-ray telescopes – they're very different instruments, but they're still measuring parts of the electromagnetic spectrum. It's just to do with the frequency of the waves, and with gravitational waves it's exactly the same.

Dr Paul McNamara, project scientist on the European Space Agency's LISA Pathfinder mission

ASTRONOMY

What will the Vera C. Rubin Observatory do?

The Vera C. Rubin Observatory is the site in Chile where we are building this giant telescope. It's going to survey the entire night sky of the Southern Hemisphere, so every few days there will be a new image of pretty much every chunk of sky. After ten years – which is how long the survey is going to last – we will have a high-resolution full-colour movie of the night sky. We'll be able to see lots of things that are changing and maybe discover new science, and also see really faint structures that we haven't been able to see before. It's everything from asteroid discovery and Solar System science to figuring out the fate of the universe. It really encompasses all areas of astronomy, which is why it's super cool.

The data is going to be published and made available to all astronomers in the US and Chile. It will be immediately made public, and then a subset of it will be going public globally. Then it will be made fully public two years after the fact, so we really want to enable science on a large scale.

Dr Meredith Rawls, stellar astronomer and software developer working as a research scientist with the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) group at the University of Washington

▼ Full survey operations are expected to start in October 2024

COSMOLOGY

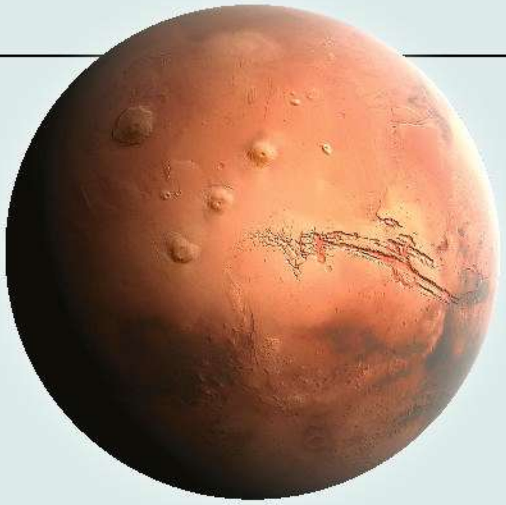
Could a true fundamental theory of the universe exist that's too difficult for us to grasp?

Sometimes I think there must be an ultimate reality and there must be an ultimate explanation. But then other times I wonder whether there is an all-encompassing theory of everything that you could stick on your T-shirt, because so far we've been able to unify ideas.

We didn't know electricity and magnetism were connected to each other, but we found out that they are. We thought Newton's theory of gravity was right, but then Einstein came along and said, "no, it's all about geometry and the shape of space and time," and so on. Then we developed quantum mechanics, which describes all the subatomic particles, and that unifies lots of ideas.

We keep thinking we're finding deeper, simpler, more unified theories, and we think ultimately there must be some theory of everything. But maybe there isn't. Quantum physics describes the world as very small and Einstein's general theory of relativity describes the entire universe – we're never going to find something that will explain everything in one simple idea.

Professor Jim Al-Khalili, one of Britain's most respected theoretical physicists, author and television presenter



SOLAR SYSTEM

What will Mars be like in the next billion years?

One of the curious things about Mars is that because it doesn't have a large moon to stabilise its axis of rotation, it flops around in an entirely chaotic and unpredictable manner.

Currently, the axis is at 25 degrees to the orbital plane – similar to that of Earth – and it has summer and winter seasons just like us. But in the past the axis has been anywhere between 0 and 60 degrees, and this has enormous effects on the Martian climate. If the axis was at 40 degrees, both ice caps would melt and we'd see free water on the surface of Mars again. And it wouldn't take a billion years… just a few thousand would do it.

Dr Simon Morden, planetary scientist and award-winning science-fiction writer

SPACE EXPLORATION

What are the major technical challenges involved in manned missions to the moon?

Sending humans to the Moon is a massive technical undertaking, even with modern technology. The list of challenges includes life-support systems, water, food, sanitation, radiation, medical needs, communications… and the list goes on. All of the equipment and consumables needed to do those things need to be launched from Earth and transported to the Moon. Weight is at an absolute premium when transporting things to the lunar surface, so there's a strong drive to reduce the mass of all of those things. But if you reduce it too far you run the risk of catastrophic equipment failures or running out of critical supplies. Balancing all those needs requires a lot of effort and will also need a lot of new technologies.

Andrew Barton, director of launch and US operations for Fleet Space Technologies

Mars does have two small moons, but they have little influence on it

The Space Shuttle is one of the most iconic spacecraft

NASA is gearing up to return to the Moon in the next few years

United States

SPACE EXPLORATION

Was it the right decision to retire the Space Shuttle?

If you'd asked me back in 2003, which is when the decision was made to retire the Shuttle, I would have said of course this is right after losing Columbia. Losing two out of the five Space Shuttles is not great odds, and if we continued to fly this thing for another 20 years, chances were we were going to lose another one.

At the time I would've said – knowing that something else was on the horizon – it's probably not a bad idea for us to move on. But as the days got closer and then the Obama administration cancelled the Constellation program, we realised there was going to be a substantial gap between the Shuttle and whatever followed it. At those moments I gave pause and regretted feeling the way I did back in 2003, that it was a good idea to shut the Shuttle program down.

I think looking at all the events that transpired between 2003 and 2010, the wise thing would have been to preserve America's access to low-Earth orbit [LEO] and to continue flying the Shuttle until we had clear direction and an approved plan by Congress to get back to LEO at a defined date. After realising the impact of it, I would have said we should keep flying it perhaps just twice a year to know that we can get to LEO and we're not reliant exclusively on the Russians.

Christopher J. Ferguson, retired US Navy Captain and former NASA astronaut

© Getty Images

RUN A MESSIER MARATHON

This March there are galaxies, nebulae and star clusters galore – see how many you can spot in *All About Space*'s spring deep-sky challenge

Now is one of the best times of the year to be looking up at the night sky. In the weeks around the spring equinox on 20 March, the nights remain relatively long and the winter constellations are still hanging around. But the summer constellations are also starting to make an appearance too. For many amateur astronomers, this is Messier marathon season – a chance to catch many of the stunning nebulae, clusters and galaxies that the Messier catalogue has to offer, and all in one evening.

This famous set of objects is named after 18th-century French comet hunter Charles Messier. He compiled a list of fuzzy night-sky objects that those looking for comets might readily confuse with the real thing. With a few posthumous additions, his impressive list now boasts 110 entries, including some of the most famous objects in the sky, such as the Orion Nebula, the Pleiades star cluster and the Andromeda Galaxy. While it is possible, trying to hunt down all 110 in one evening is quite a task. In this guide we've put together 30 of the most accessible and beautiful Messier targets that you can find from dusk until dawn.

As these objects are quite faint, you're going to need binoculars in all but a few extreme cases. There are some targets – often distant galaxies – that will also require a small telescope. Reflector telescopes are often the best choice here because you can collect more light for a cheaper price. It's also best to avoid nights when a bright Moon is present. The weekend of 20 to 22 March would be ideal. If you've not tried your hand at finding globular clusters, galaxies and giant cosmic gas clouds before, there's never been a better time to start. Enjoy your Messier marathon.

1 Messier 39 (NGC 7092)

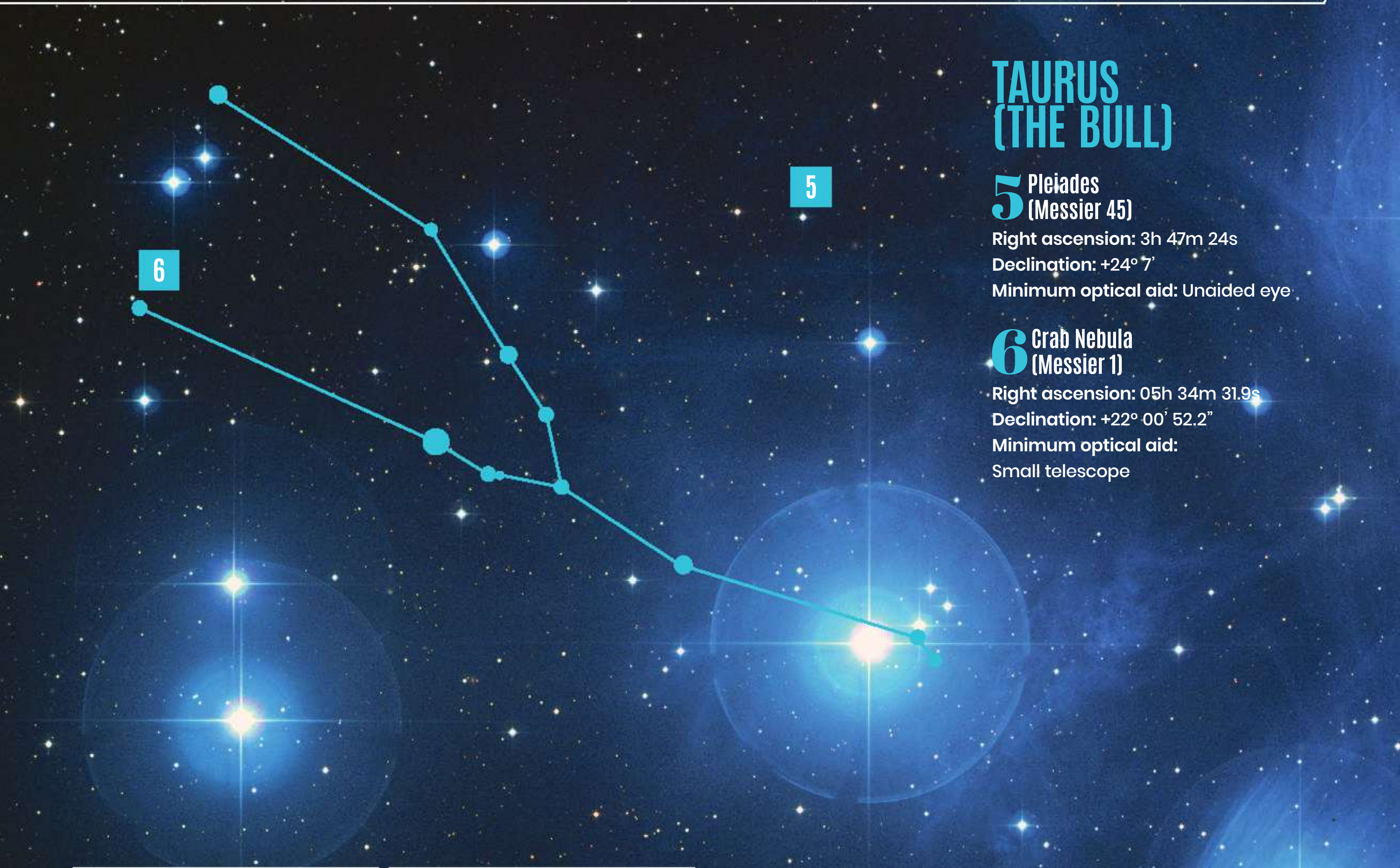
Right ascension: 21h 31m 42s
Declination: +48° 25'
Minimum optical aid: Binocular

We start our journey low down in the north as soon as it gets dark. The constellation of Cygnus (the Swan) – part of the Summer Triangle – is just skirting the horizon. If you can see the brightest star in Cygnus, Deneb, trace a diagonal line up to the left with your binocular and you should find this cluster. There are other clusters in quite close proximity which aren't part of the Messier catalogue, but you're looking for the brightest of the group.

2 Andromeda Galaxy (Messier 31)

Right ascension: 00h 42m 44.3s
Declination: +41° 16' 9"
Minimum optical aid: Unaided eye

We're moving slightly to the west and higher in the sky than Messier 39. This famous object sits around 2.5 million light years from us, making it our nearest major galaxy. The first step is to find the W-shaped constellation of Cassiopeia. The three stars on the right of the 'W' form an arrow that, if followed, will roughly guide you to Andromeda.



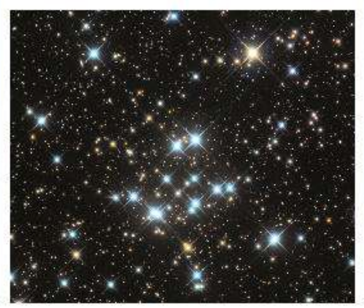
TAURUS (THE BULL)

5 Pleiades (Messier 45)

Right ascension: 3h 47m 24s
Declination: +24° 7'
Minimum optical aid: Unaided eye

6 Crab Nebula (Messier 1)

Right ascension: 05h 34m 31.9s
Declination: +22° 00' 52.2"
Minimum optical aid:
Small telescope



3 Triangulum Galaxy (Messier 33)

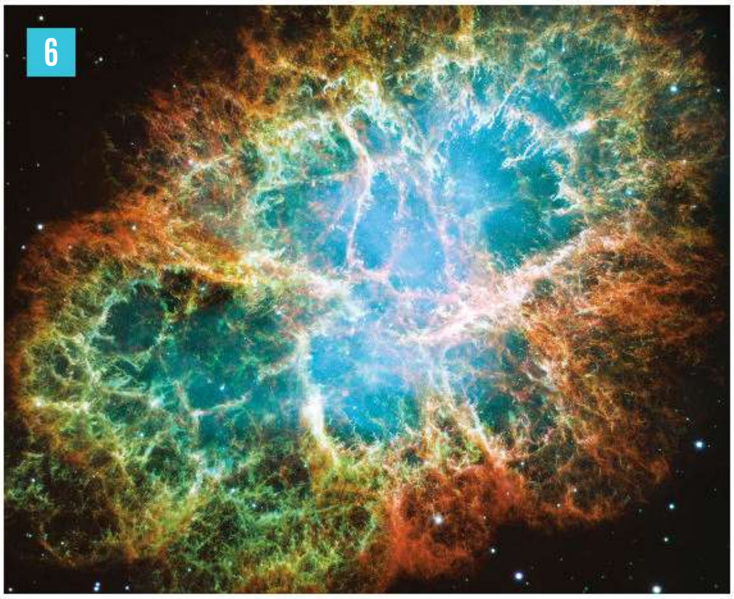
Right ascension: 01h 33m 50s
Declination: +30° 39' 36.7"
Minimum optical aid: Binocular

Now move back down that line of three stars, returning to Mirach. Then continue that line towards another three stars which make up the constellation of Triangulum (the Triangle). Before you get there you should come across the fuzzy patch of the Triangulum Galaxy. The galaxy sits slightly to the right of the centre point of the line between Mirach and Hamal in Aries.

4 Messier 34 (NGC 1039)

Right ascension: 02h 42.1m
Declination: +42° 46'
Minimum optical aid: Binocular

From Messier 33, head about 12 degrees higher in the sky and slightly to the right. Here you'll encounter Almaak – a star that forms part of Andromeda's feet. Now turn your gaze up and to the left towards Algol in Perseus. In between these two stars you'll find the open cluster Messier 34. The stars here are thought to be relatively young – only 250 million years old.



7 Orion Nebula (Messier 42)

Right ascension: 05h 35m 17.3s
Declination: -05° 23’ 28”
Minimum optical aid: Unaided eye

Lower in the sky and further towards the south is the constellation of Orion. Nestled under his belt are three ‘stars’ in an almost vertical line. The middle one is the Orion Nebula. In unpolluted skies the area will look fuzzy even without binoculars. It’s the nearest star-forming region to Earth, with gravity gradually sculpting new stars out of the huge swathes of gas and dust that lurk here.

8 Messier 50 (NGC 2323)

Right ascension: 07h 03.2m
Declination: -08° 20’
Minimum optical aid: Binocular

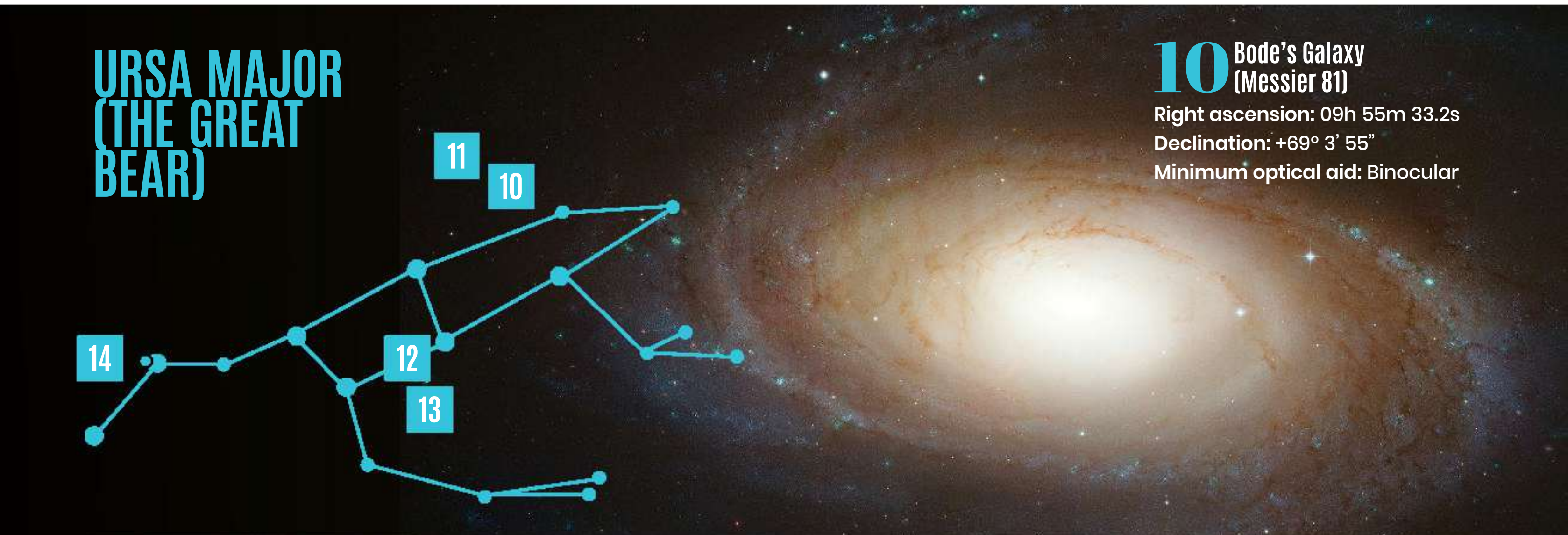
Follow Orion’s Belt down to the left and you’ll come across Sirius. Kick up and to the left and the next bright star you’ll encounter will be Procyon in Canis Minor. Messier lies about a third of the way along the line between Sirius and Procyon. Omega Canis Majoris also sits almost exactly halfway between Messier 50 and Sirius, which can be a useful way to check, as other clusters lie nearby.

9 Beehive Cluster (Messier 44)

Right ascension: 08h 40.4m
Declination: 19° 59’
Minimum optical aid: Unaided eye

Above Procyon sit the two bright stars Castor and Pollux – the heads of Gemini (the Twins). Join those two stars and follow the resulting line downwards and to the left. Messier 44, often referred to as Praesepe, is the highlight of the otherwise extremely uninteresting constellation of Cancer (the Crab).

URSA MAJOR (THE GREAT BEAR)



10 Bode’s Galaxy (Messier 81)

Right ascension: 09h 55m 33.2s
Declination: +69° 3’ 55”
Minimum optical aid: Binocular

11 Cigar Galaxy (Messier 82)

Right ascension: 09h 55m 52.2s
Declination: +69° 40’ 47”
Minimum optical aid: Binocular

12 Surfboard Galaxy (Messier 108)

Right ascension: 11h 11m 31s
Declination: +55° 40’ 27”
Minimum optical aid: Small telescope

13 Owl Nebula (Messier 97)

Right ascension: 11h 14m 47.7s
Declination: +55° 01’ 08.50”
Minimum optical aid: Larger binocular

14 Pinwheel Galaxy (Messier 101)

Right ascension: 14h 03m 12.6s
Declination: +54° 20’ 57”
Minimum optical aid: Binocular

15 Whirlpool Galaxy (Messier 51)

Right ascension: 13h 29m 52.7s
Declination: +47° 11' 43"
Minimum optical aid: Binoculars

Skip back across Alkaid – the tail's end star of Ursa Major – and you'll find one of the most beautiful galaxies in the sky. It's actually two galaxies interacting with each other, Messier 51 and NGC 5195. The existence of the companion has been known about since the middle of the 19th century, when the Earl of Rosse drew what he saw through his giant 72-inch telescope in Ireland.

16 Messier 3 (NGC 5272)

Right ascension: 13h 42m 11.6s
Declination: +28° 22' 38.2"
Minimum optical aid: Binocular

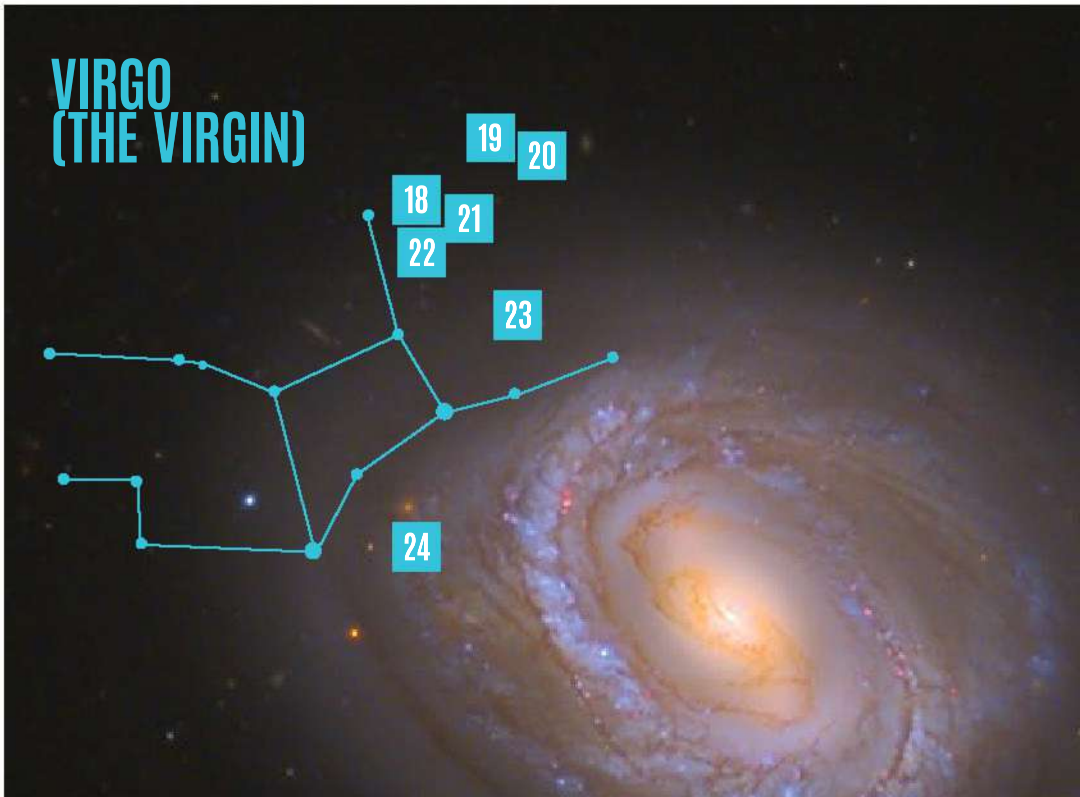
Moving away from Alkaid, you'll come across the two stars that make up the heads of Canes Venatici. Join the line between them and follow it down towards the horizon. One of the finest clusters sits just over halfway between Cor Caroli of Canes Venatici and Arcturus in Boötes.

17 Messier 53 (NGC 5024)

Right ascension: 13h 12m 55.3s
Declination: +18° 10' 05.4"
Minimum optical aid: Binocular

Go back to Arcturus. Now look up to the right a little and find the star Muphrid. Extend the line between them up and to the right until you encounter the star Diadem in Coma Berenices. Globular cluster Messier 53 lies just a degree away. It's one of the most distant globular clusters.

VIRGO (THE VIRGIN)



18 Messier 58 (NGC 4579)

Right ascension: 12h 37m 43.5s
Declination: +11° 49' 05"
Minimum optical aid: Small telescope

19 Messier 86 (NGC 4406)

Right ascension: 12h 26m 11.7s
Declination: +12° 56' 46"
Minimum optical aid: Binocular

20 Messier 84 (NGC 4374)

Right ascension: 12h 25m 03.7s
Declination: +12° 53' 13"
Minimum optical aid: Binocular

21 Messier 59 (NGC 4621)

Right ascension: 12h 42m 02.3s
Declination: +11° 38' 49"
Minimum optical aid: Small telescope

22 Messier 60 (NGC 4649)

Right ascension: 12h 43m 39.6s
Declination: +11° 33' 09"
Minimum optical aid: Binocular

23 Messier 61 (NGC 4303)

Right ascension: 12h 21m 54.9s
Declination: +04° 28' 25"
Minimum optical aid: Small telescope

24 Sombrero Galaxy (Messier 104)

Right ascension: 12h 39m 59.4s
Declination: -11° 37' 23"
Minimum optical aid: Binocular

25 Southern Pinwheel Galaxy (Messier 83)

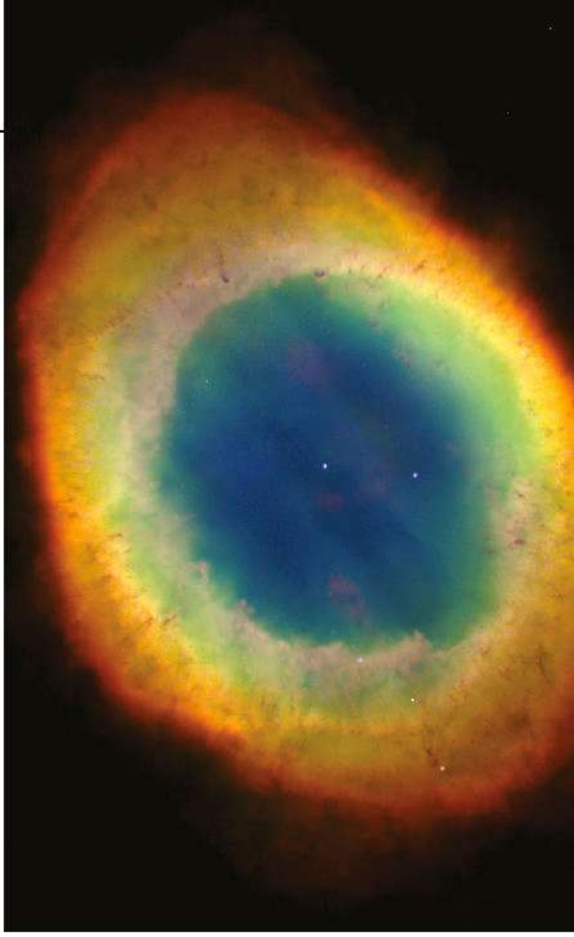
Right ascension: 13h 37m 01s
Declination: -29° 51' 57"
Minimum optical aid: Binocular

The Southern Pinwheel Galaxy is located on a line that starts with the star Alchiba in Corvus and passes through Messier 68. It sits less than a degree away from the magnitude +5.8 star HIP 66563. No fewer than six supernovae have been recorded exploding in this star city.

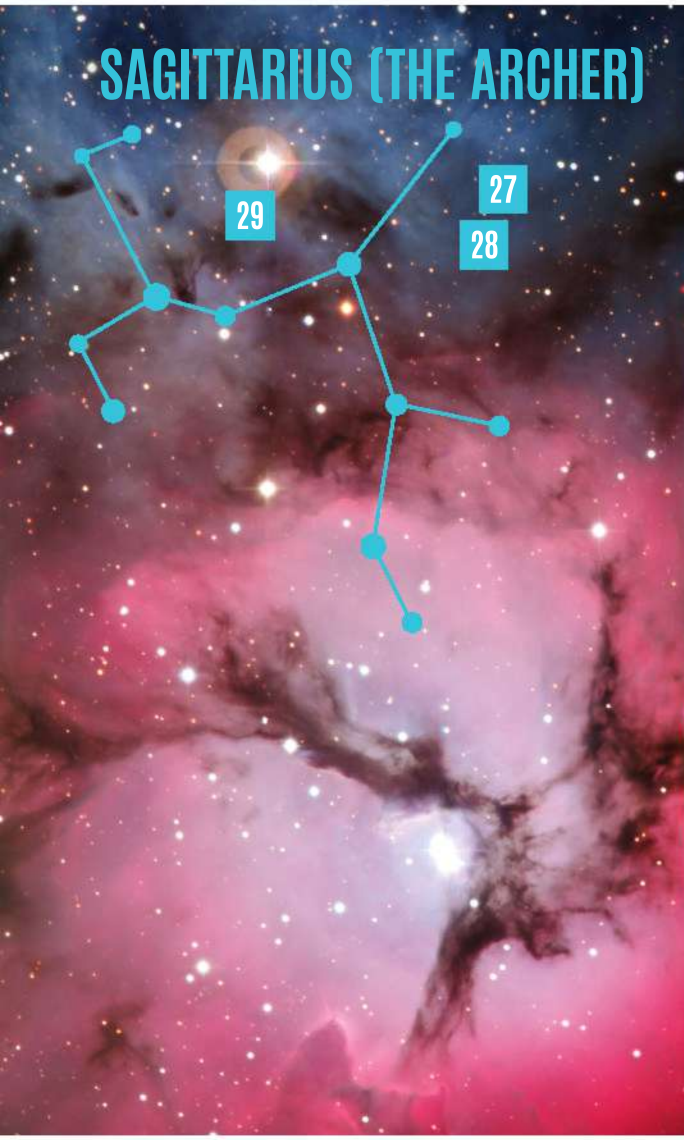
26 Ring Nebula (Messier 57)

Right ascension: 18h 53m 35s
Declination: +33° 01' 45"
Minimum optical aid: Binocular

The Ring Nebula is a warning – a sign of the fate that awaits the Sun. To see it for yourself, head down and left from Messier 13 in the constellation of Hercules until you reach the stupendously bright star Vega in Lyra. Then head down towards the horizon and you'll find the star Sulafat. The star Sheliak lies diagonally up to the right. Approximately halfway between them you'll find the Ring Nebula – a star that has shed its outer layers at the end of its life. Our Sun will do the same in around 5 billion years.



SAGITTARIUS (THE ARCHER)



27 Trifid Nebula (Messier 20)

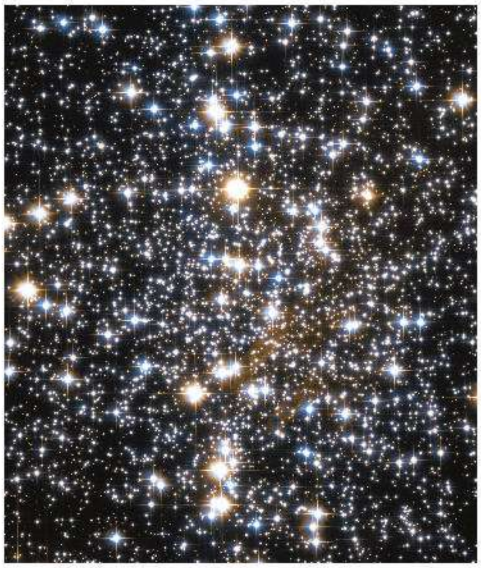
Right ascension: 18h 02m 23s
Declination: -23° 01' 48"
Minimum optical aid: Binocular

28 Lagoon Nebula (Messier 8)

Right ascension: 18h 03m 37s
Declination: -24° 23' 12"
Minimum optical aid: Binocular

29 Sagittarius Cluster (Messier 22)

Right ascension: 18h 36m 23.9s
Declination: -23° 54' 17.1"
Minimum optical aid: Borderline unaided eye



30 Messier 4 (NGC 6121)

Right ascension: 16h 23m 35.2s
Declination: -26° 31' 32.7"
Minimum optical aid: Binoculars

Head towards the dazzlingly bright and brilliant red star Antares in Scorpius. Just 1.5 degrees to the right and less than half a degree down is Messier 4. Due to its proximity to one of the brightest and best-known stars in the sky, it's one of the most accessible globular clusters. It was the first globular cluster from which astronomers were able to pick out individual stars. If you have a medium-sized telescope you may well be able to do the same – a great way to conclude a night's observing!

© NRAO; NASA; Adam Evans; Alexander Meleg; ESA; Hunter Wilson;

FEED YOUR MIND

www.howitworksdaily.com

AMAZING FACTS
SCIENCE UP CLOSE
ILLUSTRATIONS
INSIDE GADGETS
COOLEST TECH
BUY YOUR ISSUE TODAY!
HOW THE ASTEROID BELT FORMED
HOW IT WORKS
FACIAL RECOGNITION EXPLAINED
452 deadly volcanoes
40 lightning strikes a minute
+ > WHY NETTLES STING > RIP CURRENTS EXPLAINED > MONSTER VEHICLES
EXTREME EARTH
EXPLORE THE MOST HOSTILE PLACES ON THE PLANET AND LEARN HOW LIFE SURVIVES THERE
A crushing eight tonnes of pressure
Bone-chilling -93.2°C cold
Toxic pH 12 alkaline lake
PIG-HUMAN HEART TRANSPLANT FIRST
HOW WOLVES BECAME DOGS
ISSUE 174
FUTURE

HOW IT WORKS

Print and digital subscriptions available at

www.magazinesdirect.com/know3for3

Also available from all good newsagents and supermarkets

How It Works magazine @HowItWorksmag howitworks@futurenet.com howitworksmag

WHAT’S IN THE SKY?

What to look out for during this observing period

In this issue...

78 What’s in the sky? With spring coming, get out while it’s still dark enough

80 Planetarium Where you can find the planets this month and the phases of the Moon

82 Month’s planets Venus takes pride of place in the evening sky

84 Moon tour Track down one of the most infamously mysterious craters on the lunar surface

85 Naked eye and binocular targets Take a tour of Leo, Cancer and Gemini this evening, without the need of a telescope

86 Deep sky challenge The evenings of early spring are full of deep-sky objects

88 The Northern Hemisphere The spring constellations are teeming with galaxies for deep-sky enthusiasts

90 Your astrophotos The best of our readers’ astrophotography images

92 Review We build the LEGO International Space Station

96 In the shops Our pick of the best gifts and accessories for astronomy and space fans

25 FEBRUARY

The Moon and Uranus make a close approach, within 1°10’ of each other in Aries

28 FEBRUARY

The Moon and Mars make a close approach, within 1°03’ of each other in Taurus

28 FEBRUARY

The Moon will pass in front of Mars, visible from eastern Greenland and western Russia

28 FEBRUARY

Conjunction between the Moon and Mars in Taurus

2 MARCH

Jupiter and Venus make a close approach, within 29.4’ of each other in Pisces

2 MARCH

Conjunction between Venus and Jupiter in Pisces

13 MARCH

The Moon will pass in front of Delta Scorpii, creating a lunar occultation

20 MARCH

March equinox

> “Dwarf planet Ceres reaches opposition in Coma Berenices”

21 MARCH

Dwarf planet Ceres reaches opposition in Coma Berenices

24 MARCH

The Moon and Venus make a close approach, passing within 6’ of each other in Aries

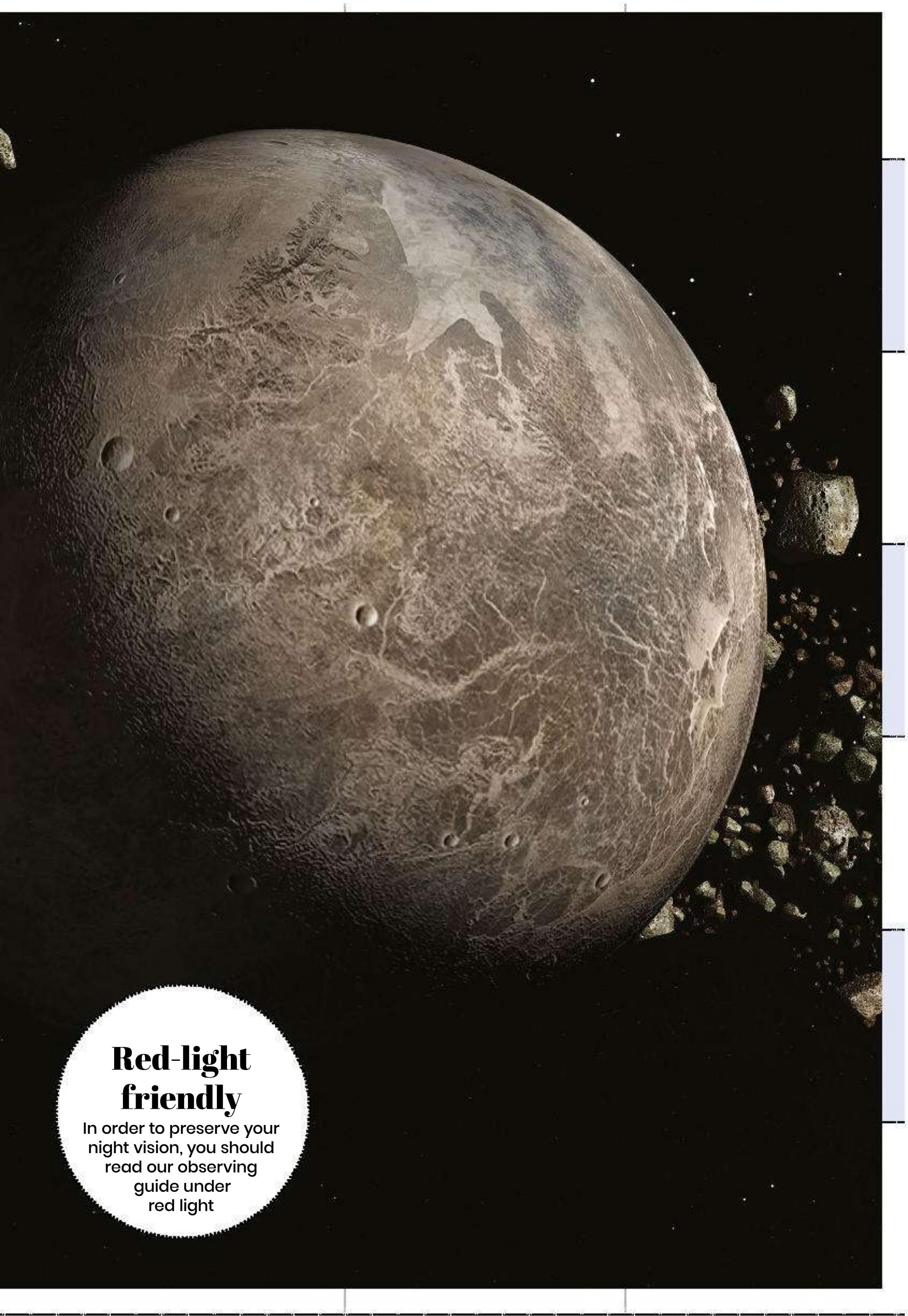
24 MARCH

Conjunction between the Moon and Venus in Aries

24 MARCH

The Moon will pass in front of Venus, creating a lunar occultation visible from Asia and Africa

Naked eye
TAKE CARE!
Naked eye warning
Binoculars
Small telescope
Medium telescope
Large telescope
Solar eclipse
Solstice



Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

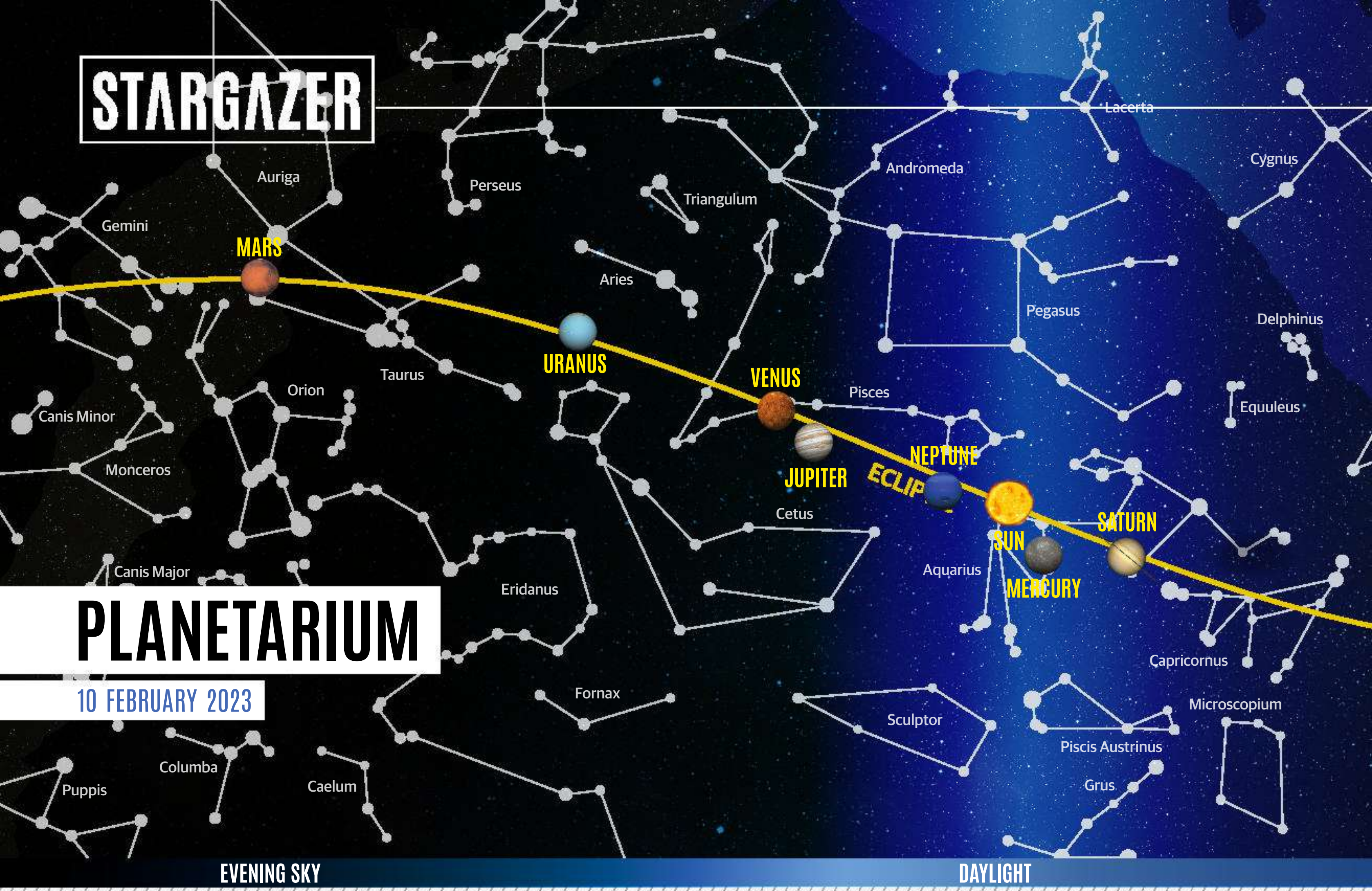
Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

© Getty Images

PLANETARIUM

10 FEBRUARY 2023


Auriga
Perseus
Triangulum
Lacerta
Cygnus
Andromeda
Gemini
MARS
Aries
Pegasus
Delphinus
URANUS
Taurus
VENUS
Pisces
Orion
Canis Minor
Equuleus
JUPITER
NEPTUNE
ECLIP
Monceros
Cetus
SUN
SATURN
Aquarius
MERCURY
Canis Major
Eridanus
Capricornus
Fornax
Microscopium
Sculptor
Piscis Austrinus
Columba
Puppis
Caelum
Grus
EVENING SKY
DAYLIGHT

MOON CALENDAR

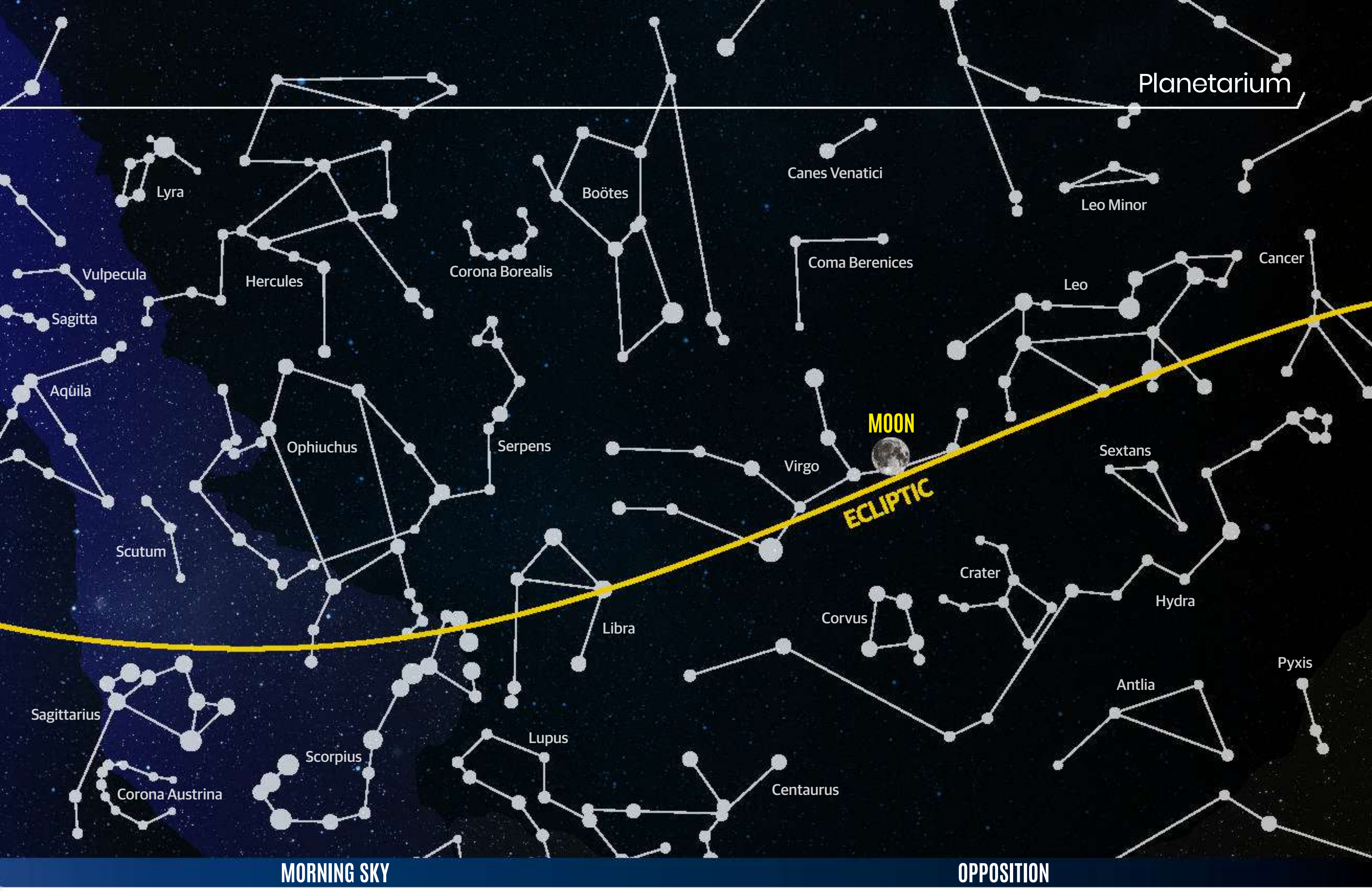
* The Moon does not pass the meridian on 7 March

Date	Phase	Illumination	Times
23 FEB		14.9%	◓ 08:27 ◒ 21:58
24 FEB		23.9%	◓ 08:41 ◒ 23:20
25 FEB		33.8%	◓ 08:57 ◒ --:--
26 FEB		44.1%	◒ 00:40 ◓ 09:16
27 FEB	FQ	54.3%	◒ 01:58 ◓ 09:41
28 FEB		64.1%	◒ 03:10 ◓ 10:14
1 MAR		73.3%	◒ 04:12 ◓ 10:58
2 MAR		81.4%	◒ 05:03 ◓ 11:54
3 MAR		88.3%	◒ 05:41 ◓ 12:59
4 MAR		93.8%	◒ 06:08 ◓ 14:10
5 MAR		97.6%	◒ 06:29 ◓ 15:22
6 MAR		99.6%	◒ 06:45 ◓ 16:35
7 MAR	FM	--.-*%	◒ 06:58 ◓ 17:48
8 MAR		99.7%	◒ 07:10 ◓ 19:00
9 MAR		97.7%	◒ 07:21 ◓ 20:13
10 MAR		93.7%	◒ 07:32 ◓ 21:28
11 MAR		87.7%	◒ 07:45 ◓ 22:47
12 MAR		79.9%	◒ 08:01 ◓ --:--
13 MAR		70.4%	◓ 00:08 ◒ 08:22
14 MAR		59.7%	◓ 01:31 ◒ 08:52
15 MAR	TQ	48.2%	◓ 02:49 ◒ 09:37
16 MAR		36.5%	◓ 03:55 ◒ 10:39
17 MAR		25.3%	◓ 04:45 ◒ 11:59
18 MAR		15.4%	◓ 05:20 ◒ 13:29
19 MAR		7.6%	◓ 05:45 ◒ 15:02
20 MAR		2.4%	◓ 06:03 ◒ 16:33
21 MAR	NM	0.1%	◓ 06:18 ◒ 18:01
22 MAR		0.9%	◓ 06:32 ◒ 19:27
23 MAR		4.5%	◓ 06:45 ◒ 20:52

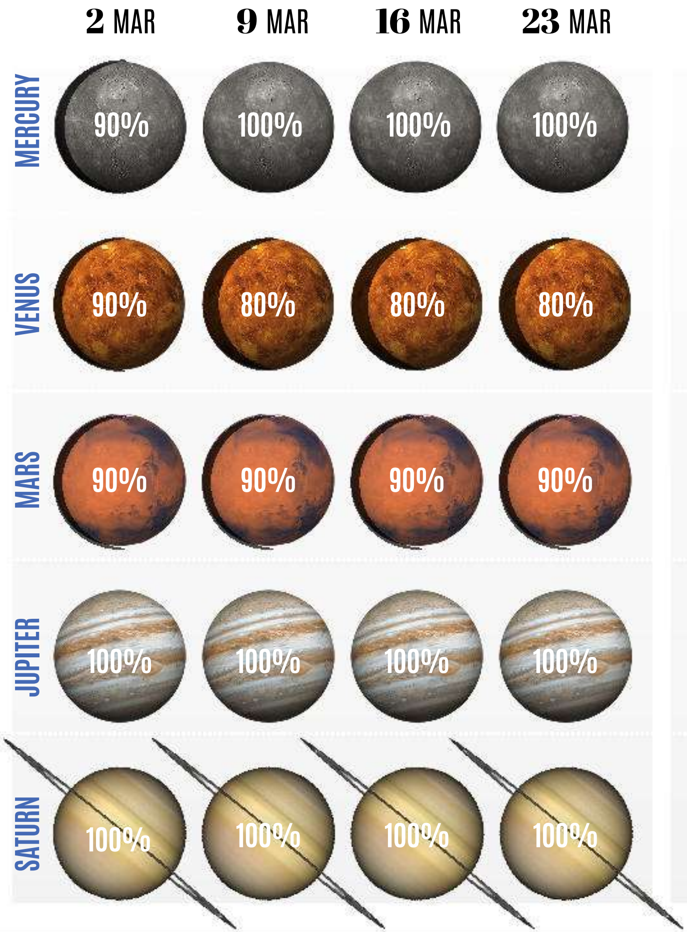
% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)


Lyra
Boötes
Canes Venatici
Leo Minor
Vulpecula
Hercules
Corona Borealis
Coma Berenices
Cancer
Leo
Sagitta
Aquila
Ophiuchus
Serpens
Virgo
MOON
ECLIPTIC
Sextans
Scutum
Crater
Hydra
Corvus
Libra
Pyxis
Antlia
Sagittarius
Lupus
Scorpius
Corona Austrina
Centaurus
MORNING SKY
OPPOSITION

ILLUMINATION PERCENTAGE



	2 MAR	9 MAR	16 MAR	23 MAR
MERCURY	90%	100%	100%	100%
VENUS	90%	80%	80%	80%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

PLANET POSITIONS

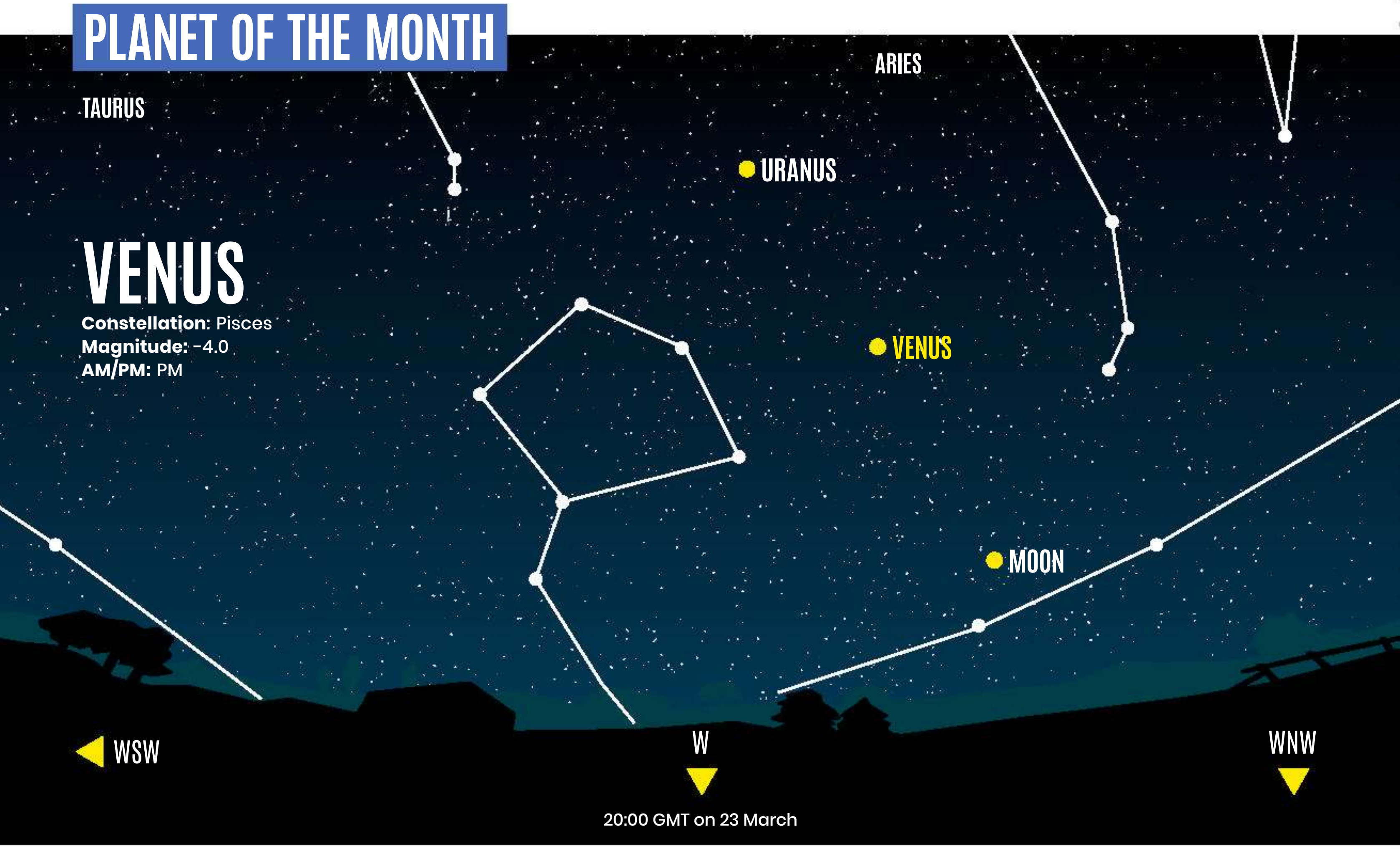
All rise and set times are given in GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
23 FEB	21h 25m 14s	-17° 11' 22"	Capricornus	-0.4	06:39	15:41
2 MAR	22h 10m 32s	-13° 34' 24"	Aquarius	-0.7	06:36	16:15
9 MAR	22h 57m 10s	-08° 53' 57"	Sagittarius	-1.2	06:30	16:58
16 MAR	23h 45m 25s	-03° 13' 52"	Pisces	-1.9	06:22	17:47
23 MAR	00h 35m 13s	+03° 11' 20"	Pisces	-1.6	06:11	18:41
23 FEB	00h 16m 46s	+00° 51' 17"	Pisces	-4.0	07:55	20:06
2 MAR	00h 47m 51s	+04° 30' 08"	Pisces	-4.0	07:40	20:28
9 MAR	01h 19m 02s	+08° 04' 19"	Pisces	-4.0	07:25	20:50
16 MAR	01h 50m 30s	+11° 29' 44"	Aries	-4.0	07:11	21:13
23 MAR	02h 22m 28s	+14° 42' 21"	Aries	-4.0	06:57	21:35
23 FEB	05h 01m 49s	+25° 14' 26"	Taurus	+0.3	10:16	03:20
2 MAR	05h 13m 54s	+25° 24' 26"	Taurus	+0.5	09:59	03:05
9 MAR	05h 26m 57s	+25° 31' 49"	Taurus	+0.6	09:43	02:52
16 MAR	05h 40m 49s	+25° 35' 39"	Taurus	+ 0.7	09:29	02:39
23 MAR	05h 55m 23s	+25° 35' 08"	Taurus	+ 0.8	09:16	02:26
23 FEB	00h 40m 08s	+03° 06' 10"	Pisces	-2.1	08:09	20:47
2 MAR	00h 45m 51s	+03° 43' 24"	Pisces	-2.1	07:44	20:28
9 MAR	00h 51m 44s	+04° 21' 18"	Pisces	-2.1	07:19	20:10
16 MAR	00h 57m 46s	+04° 59' 40"	Pisces	-2.1	06:54	19:51
23 MAR	01h 03m 54s	+05° 38' 16"	Pisces	-2.0	06:29	19:33
23 FEB	22h 03m 38s	-13° 15' 10"	Aquarius	+0.8	06:58	16:46
2 MAR	22h 06m 53s	-12° 58' 07"	Aquarius	+0.9	06:32	16:23
9 MAR	22h 10m 04s	-12° 41' 19"	Aquarius	+0.9	06:06	16:01
16 MAR	22h 13m 10s	-12° 24' 52"	Aquarius	+0.9	05:40	15:38
23 MAR	22h 16m 11s	-12° 08' 56"	Aquarius	+1.0	05:14	15:15

THIS MONTH'S PLANETS

Venus takes pride of place in the evening sky

PLANET OF THE MONTH



VENUS

Constellation: Pisces
Magnitude: -4.0
AM/PM: PM

20:00 GMT on 23 March

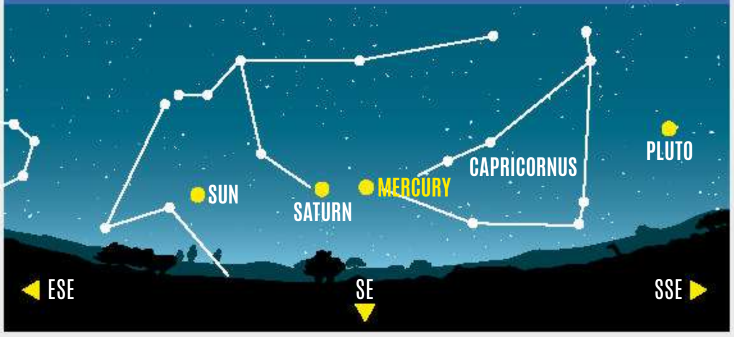
As February draws to a close, Venus will already be a very bright object, a silvery spark above the southwestern horizon that catches the eye in the twilight soon after sunset, and as the sky darkens it will become strikingly bright, so bright that many will mistake it for the lights of a plane or even the International Space Station..

On the evening of 23 February, Venus will be part of a lovely celestial gathering. Close by, to its upper left, will shine a beautiful slim crescent Moon, and between that Moon and Venus you'll see another spark of light – the planet Jupiter. This cosmic trio will look very striking to the naked eye, and even more striking through binoculars. The three objects will be bright enough for the camera on your phone to capture too, as long as you hold your phone very still and don't wait until the sky is too dark. If your phone camera has a low-light or night setting, try that and your results will be even better.

As February drifts towards March the distance between Venus and Jupiter will decrease, and the pair will begin to look like a 'double star' in the twilight. On 1 March the two planets will be side by side, less than a degree apart in the sky – or just two Moon widths – and will be a stunning sight to the naked eye. If you have binoculars they will look even more impressive. You'll see some of Jupiter's family of 80-plus moons shining close to it, looking like tiny stars. And if you have a small telescope the view will be quite spectacular. After this celestial close encounter the two planets will move apart quite quickly. Jupiter will head for the horizon, while Venus will climb higher in the sky each evening. By 3 March Venus will be setting three hours after the Sun, and shining above Jupiter now it will be a beautiful sight in the evening twilight, lantern-bright and brighter than anything else in that part of the sky.

By 23 March Venus will be a magnificent sight, setting more than three-and-a-half hours after the Sun. You really need to cross your fingers for a clear sky on that night too, because Venus will be at the far end of a glittering celestial chain. To its lower right will be a very thin crescent Moon. To the lower right of that Moon will be Jupiter, still a bright naked eye 'star', and to the lower right of Jupiter will be Mercury, looking like a copper-hued 'star' shining low in the sky, just above the western horizon.

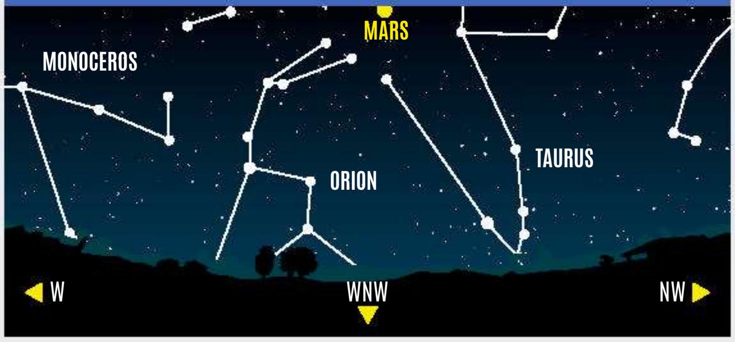
MERCURY 07:30 GMT on 28 February



Constellation: Capricornus **Magnitude:** -0.3 **AM/PM:** AM

As February draws to a close, Mercury, the closest planet to the Sun physically, is too close to the Sun visually to be seen. Although it is technically a morning object, it rises at the same time as the Sun, and as February drifts towards and then into March Mercury drifts closer and closer to the Sun until it passes behind it.

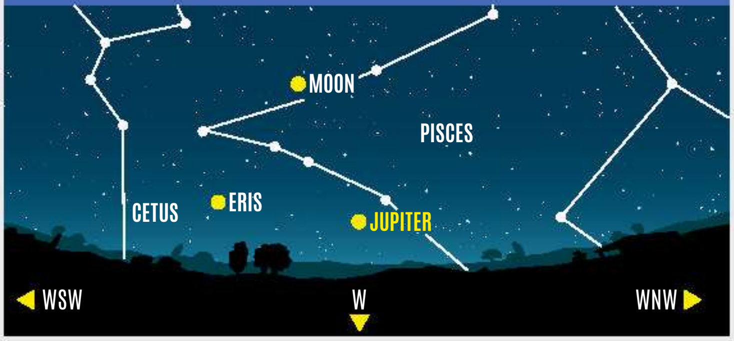
MARS 23:30 GMT on 23 March



Constellation: Taurus **Magnitude:** +0.3 **AM/PM:** PM

At the start of our observing period Mars will already be high in the southern sky as darkness falls, embedded – as it has been for many months now – in the constellation of Taurus, forming a triangle with the Hyades and Pleiades star clusters. It will be visible all through the night, setting at around 04:00.

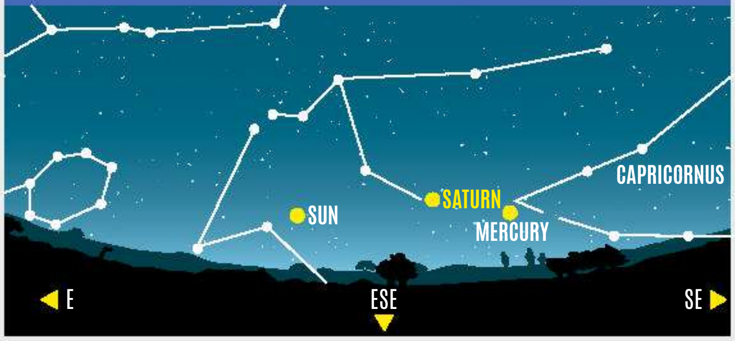
JUPITER 18:30 GMT on 23 March



Constellation: Pisces **Magnitude:** -2.1 **AM/PM:** PM

You'll notice Jupiter low in the southwest soon after sunset, shining to the upper left of much brighter Venus. As the days pass Jupiter and Venus will move closer and closer together until they appear to pass each other, with Jupiter fading and dropping down towards the horizon as Venus brightens and climbs ever higher.

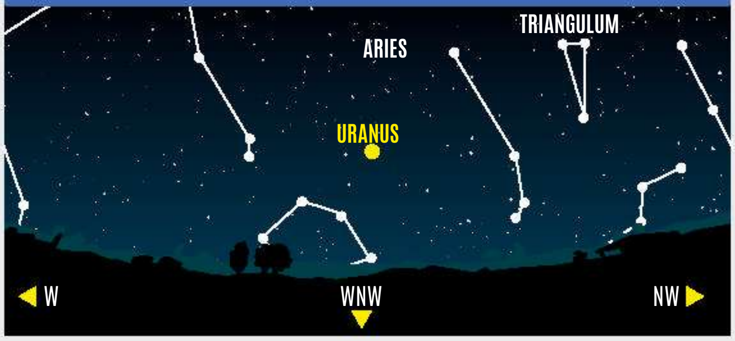
SATURN 07:30 GMT on 28 February



Constellation: Aquarius **Magnitude:** +0.8 **AM/PM:** AM

In late February Saturn will technically be a morning object, but as it rises at the same time as the Sun it won't actually be visible. By the end of March its visibility will have improved a little – it will be rising half an hour before the Sun – but at only magnitude +0.8 it will struggle to be seen in that bright sky.

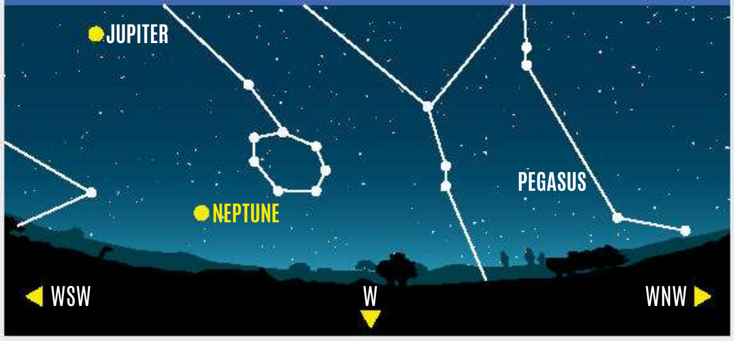
URANUS 22:30 GMT on 28 February



Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

Uranus has a subtle but noticeable green hue, making it stand out from all those blue and white stars dotted around it. In late February Uranus will be high in the south after sunset, and will set after midnight. By the end of March it will be close to much brighter Venus, but will become lost in the twilight.

NEPTUNE 17:30 GMT on 1 March



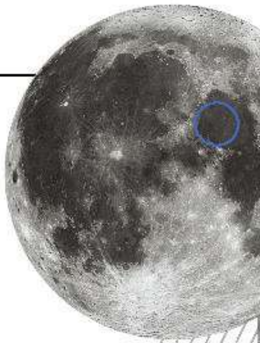
Constellation: Aquarius **Magnitude:** +8.0 **AM/PM:** PM

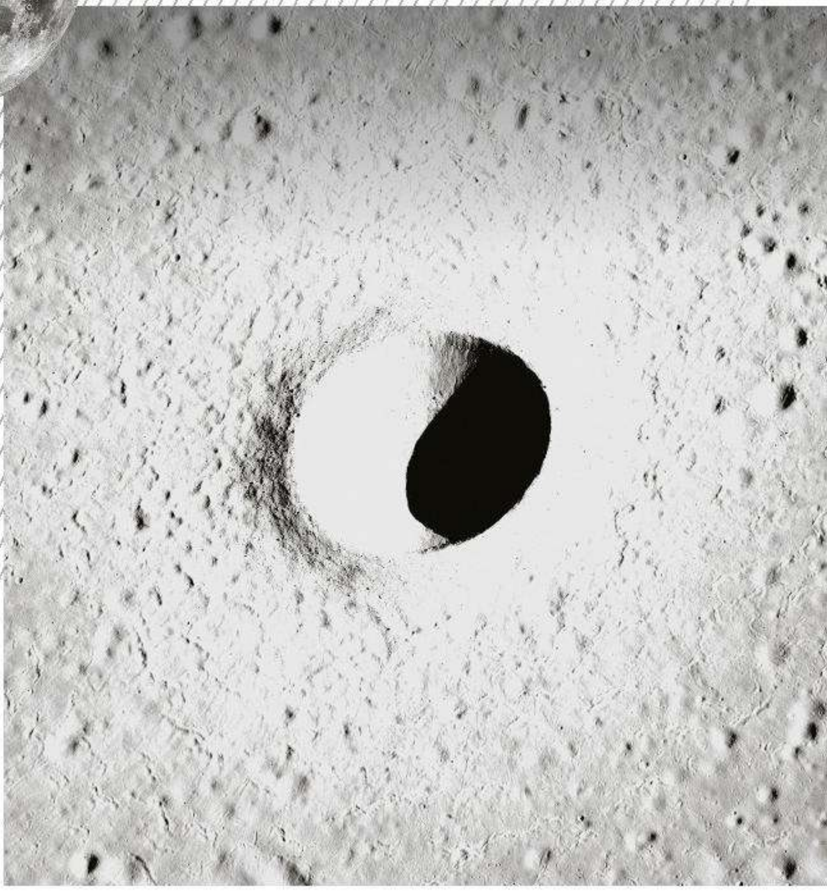
Neptune is the most distant planet from the Sun, so it's too faint to be seen by the naked eye – you'll need binoculars or a small telescope to pick it out among the stars of Aquarius. At the start of our observing period this faraway world will be an evening object, and it will set just 90 minutes after the Sun.

MOON TOUR

LINNÉ

Track down one of the most infamously mysterious craters on the lunar surface





© NASA

After centuries of intensive study with the naked eye, through telescopes and more recently using the amazingly powerful cameras of orbiting satellites, we're pretty clear on how the craters we see spattered across the face of the Moon formed – and it's really not rocket science. Over millennia, countless thousands of big rocks have come barrelling in from space, slamming into the Moon and blasting great big holes out of it.

Some of these craters are huge, measuring hundreds of kilometres across. Others are barely one kilometre (0.6 miles) from side to side. Some are surrounded by beautiful, bright rays – dust that sprayed away from the impact and then splashed back down across the Moon's surface. Most of the Moon's craters have changed in some way since they were formed. Subsequent impacts nearby have shook them up and even altered their shapes, causing their walls to slump or collapse. Many craters have vanished since they were formed, either buried beneath the debris thrown out by a younger impact or covered by tsunamis of glowing, bubbling lava.

Here and there we can see craters that have somehow managed to survive unscathed since they were formed. These are useful to planetary scientists because they allow them to study the process of crater formation very accurately. One such crater is our target this month.

Linné is a tiny crater on the western side of Mare Serenitatis. Barely two kilometres (1.2 miles) across and just 600 metres (0.37 miles) deep, it stands alone on the Sea of Serenity with no other features nearby, and has not been shaken, broken or destroyed by any other impacts close to it. It's very young – perhaps only 10 million years old – so it formed when the major bombardments of the Moon had ended, and it has managed to avoid being smashed up by any impacts since then. Although Linné is unimpressive physically, its youthfulness and almost-pristine condition make it a perfect study subject for scientists wanting to understand how craters form and change over time.

TOP TIP!

You'll see Linné's central crater pit at its best when it's close to the terminator, the line between lunar night and day

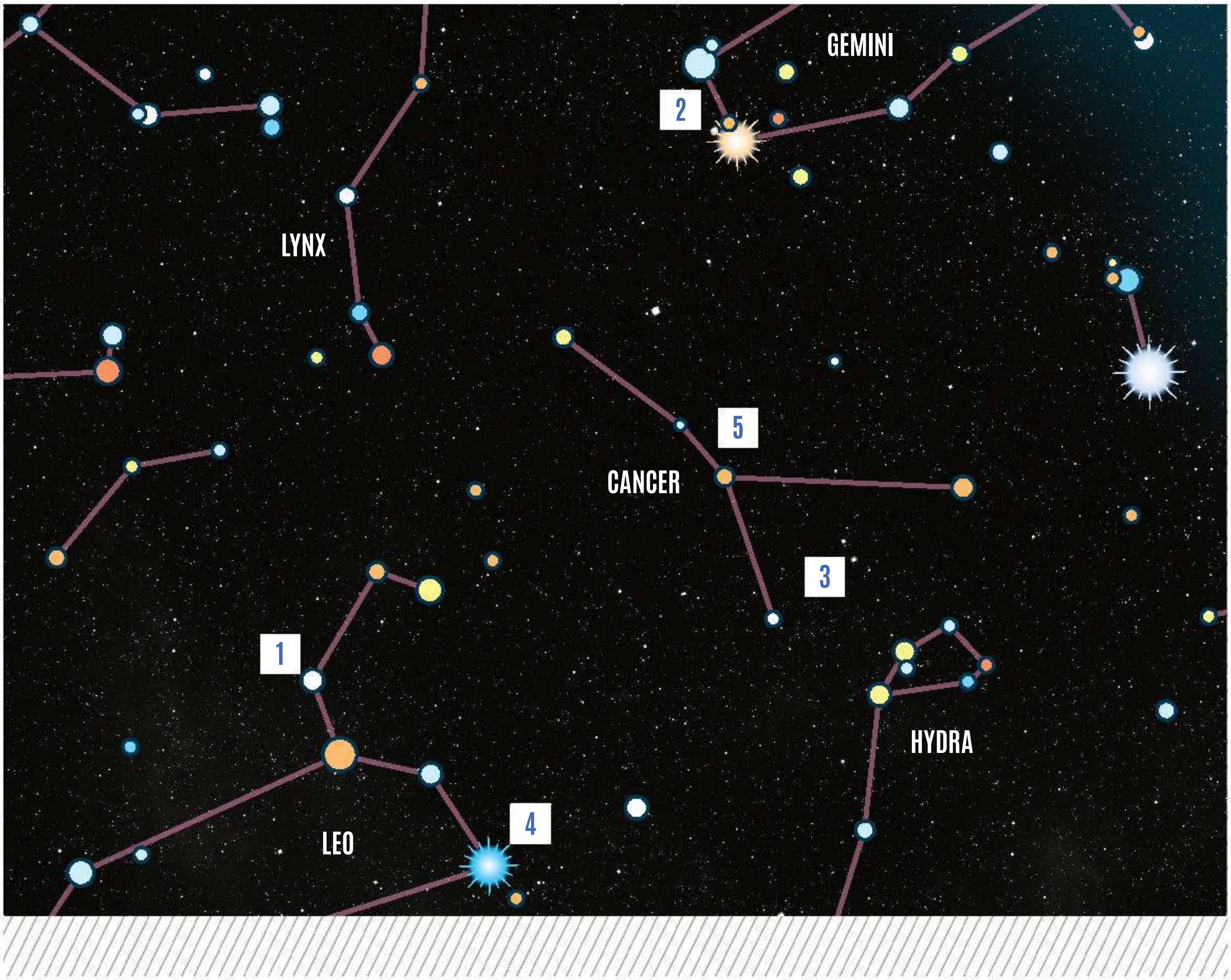
Linné was discovered by Giovanni Riccioli in the 17th century. After that it was observed frequently by others, but in 1866 Johann Friedrich Julius Schmidt made the startling claim that Linné had vanished! All he could see was a bright mound where the crater had once been. Other observers looked, and they too couldn't see the crater any more. By 1868 observers could see the crater again very clearly, and it has remained in clear view ever since. So what happened?

One theory is that Linné was leaking gas from beneath its surface in 1866, which glowed in the sunlight and obscured the crater itself from view. This idea was very controversial for a long time, but today is widely accepted – astronomers call it a 'transient lunar phenomenon'. It has been seen in or close to other lunar features, including the large crater Alphonsus.

So how can you see this strange little crater? Linné is so small it can't be seen with the naked eye, and even binoculars show it as just a tiny white spot to the right of Montes Apenninus, without any hint of the small crater pit at the centre. Small telescopes show it as a bright splash of white on the grey surface of the Moon, like the mark a piece of chalk would leave on a grey slate, and might pick out the crater at high magnification. It takes a large telescope to show the crater properly, in the centre of its bright splash of ejecta rays.

So when can you see it? The bright splash of ejecta surrounding Linné can be seen at virtually any phase of the Moon when Mare Serenitatis is illuminated, but you will only have a chance of seeing the actual crater pit when it's close to the terminator and illuminated at a low angle.

Linné will emerge from darkness on 24 February as the terminator sweeps over it. Through a telescope at high magnification, you should be able to see it. After that, as the Sun climbs higher in the sky, Linné will appear as a bright spot on the Moon, standing out starkly against the dark sea until the terminator rolls towards it again. By 10 March it will be illuminated at a very low angle again, and its crater pit should be visible briefly before it's plunged into the darkness of the long lunar night once more.



NAKED EYE AND BINOCULAR TARGETS

Take a tour of Leo, Cancer and Gemini this evening, without the need of a telescope

1 The Sickle asterism

This group of stars, looking like a backwards question mark, is the head and mane of Leo the Lion and is a sign that spring is here. The Sickle contains the blue-white star Regulus, orange Algeiba and yellow Adhafera.

2 Castor and Pollux

These two bright stars mark the heads of the Twins. Pollux, a giant star with an orange hue, is the brighter of the two stars at +1.14. Castor, which glows at a magnitude of +1.57 and with a blue-white colour, is a multiple star system – you'll need at least a small telescope to resolve these.

3 Messier 67

One of the oldest known open clusters, Messier 67 contains more than 100 stars that are similar to the Sun, along with numerous red giants. Through a small binocular you should be able to see an elongated patch of light.

4 Regulus

The brightest star in Leo, Regulus is 79 light years away and is a multiple star system. Regulus marks the bottom of 'the Sickle', an asterism which makes up the Lion's mane. Regulus is one of the brightest stars in the sky, shining with a white-blue hue at a magnitude of +1.4.

5 The Beehive Cluster (Messier 44)

A fuzzy patch of light to the naked eye, binoculars with a magnification of at least 10x50 show this lovely star cluster in all its glory. Messier 44 fits well in the field of view of a pair of binoculars and contains red giants, white dwarfs and Sun-like stars.

1 NGC 2903

DEEP SKY CHALLENGE

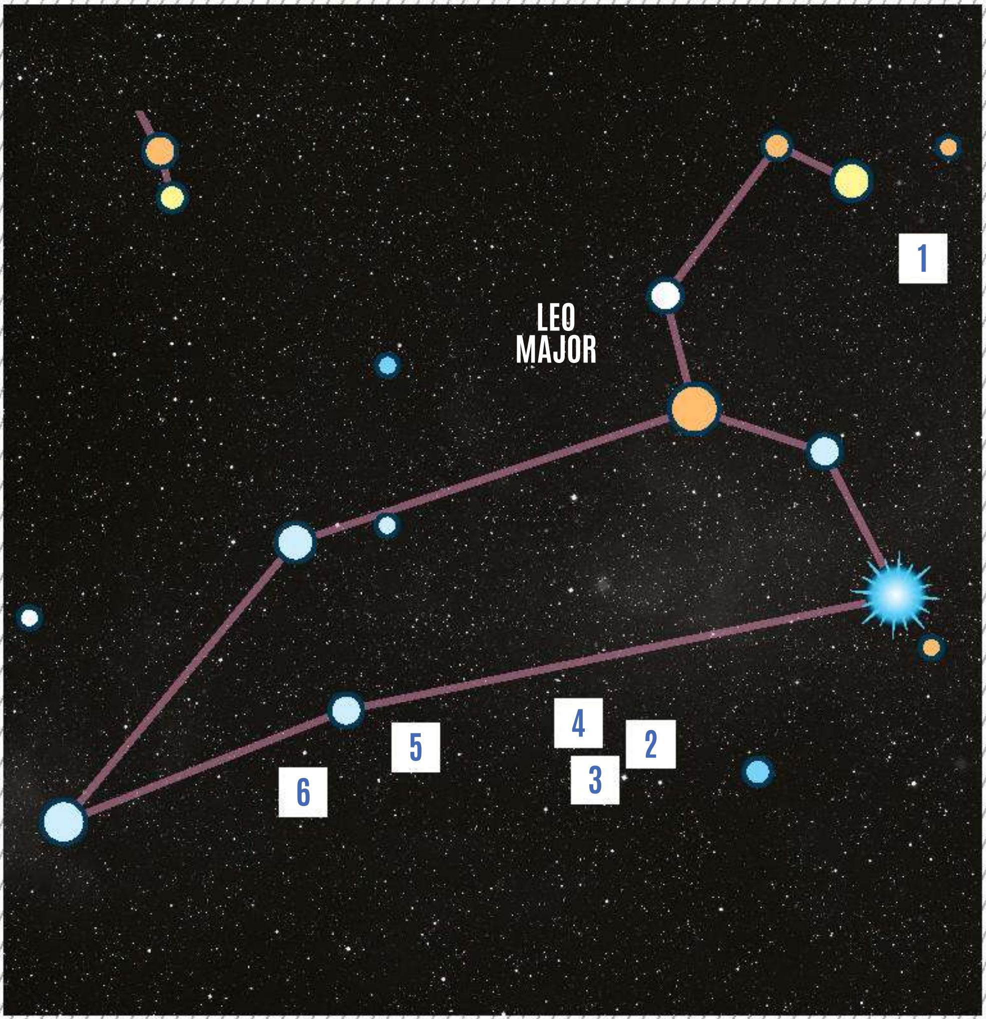
THE LION'S GALAXIES

The evenings of early spring are full of deep-sky objects

Spring is known as the season of the galaxies to astronomers, as the night side of Earth is facing away from the Milky Way and out into deep space, which is littered with other such 'island universes' as our own. The distances to these objects are truly vast, and so we often only see them as small, hazy patches of light, but these objects are anything but small. Like the Milky Way, they contain billions of stars, clusters and nebulae in their own right. They also come in various shapes and sizes and can be a little smaller or even a lot larger than our own galaxy. Due to line-of-sight effects, as well as gravitational ones, they can also seem to occur in groups, such as the Leo Triplet, or they might just appear as isolated misty patches of light, floating in the depths of space.

2 Messier 95

3 Messier 96



1 NGC 2903

The spiral galaxy NGC 2903 is considered to be 'active' due to the high rate of star birth going on in its core. Observations using modest telescope apertures reveal a bright oval embedded in a haze. Good sky conditions will reveal its spiral arms.

2 Messier 95

Look through a telescope at Messier 95 and you'll see that it's a face-on spiral galaxy. Located 38 million light years away in the Lion's belly, Messier 95 is home to a supernova that was discovered back in 2012.

3 Messier 96

Like Messier 95, this galaxy has a spiral structure and can be found in the 'stomach' of Leo. It's said that Messier 96 is of a similar size to the Milky Way at 100,000 around light years across. Small telescopes reveal a very faint patch of light – the galaxy's oval core.

4 Messier 105

Being an elliptical galaxy, Messier 105 doesn't have a great deal of detail, with even the largest telescopes showing it as a blob of light. Telescopes with apertures of at least ten inches will reveal neighbouring NGC 3384 and NGC 3389 in the same field of view.

5 NGC 3489

Large-aperture telescopes will reveal NGC 3489's bright and fuzzy core. This lenticular galaxy is 32 million light years away from Earth. With a magnitude of +10.3, it's best viewed under very good observing conditions.

6 The Leo Triplet

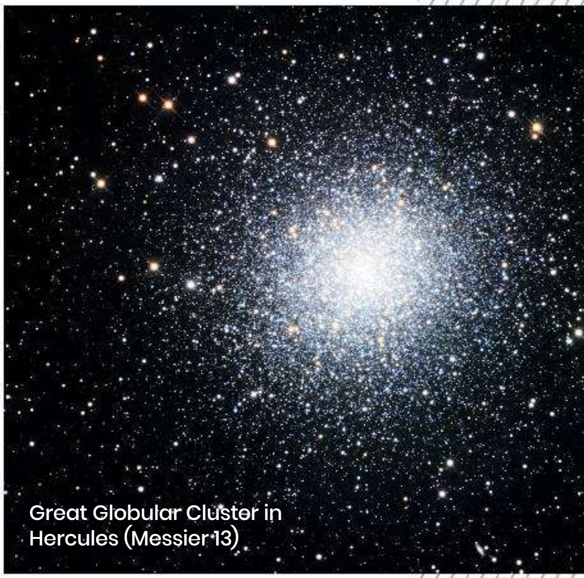
Consisting of Messier 65, Messier 66 and NGC 3628, this famous group is a popular target for those who like to dabble in astrophotography. These three large spiral galaxies can be viewed in the same field of view.

NORTHERN HEMISPHERE

The spring constellations are teeming with galaxies for deep-sky enthusiasts

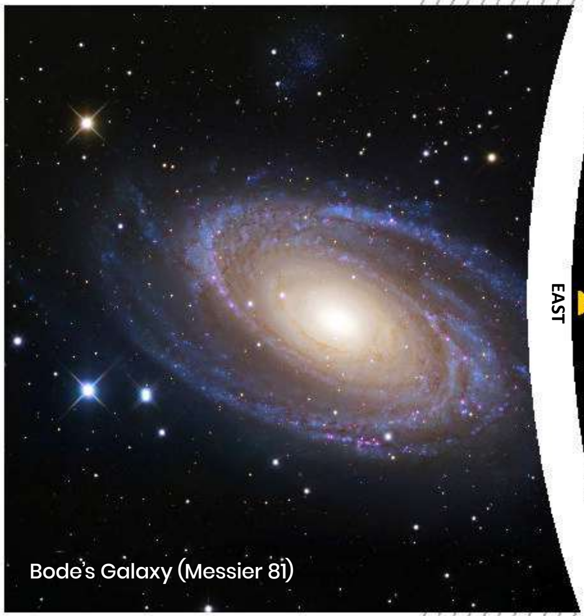
While you will have to be quick to observe the galaxies in the constellation of Andromeda as they start to head towards the horizon, those found in Virgo and Ursa Major are ideal for those with at least a small telescope. Fans of globular star clusters are in for a treat this month, as the Great Globular Cluster in Hercules (Messier 13), which shines at magnitude +5.9, and its +6.5-magnitude neighbour Messier 92 won't set until around 05:00.

If you're a fan of using binoculars, there are a variety of targets to be observed, such as the bright star system Capella in the constellation of Auriga, as well as double stars Mizar and Alcor in the handle of the Plough, or Big Dipper.



Great Globular Cluster in Hercules (Messier 13)

EAST
SERPENS CAPUT
M5

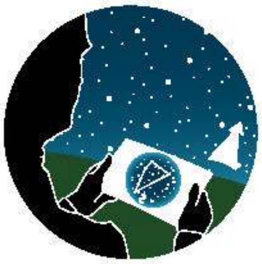


Bode's Galaxy (Messier 81)

Auriga and Taurus above Mount Everest

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.



1 Hold the chart above your head with the bottom of the page in front of you.

2 Face south and notice that north on the chart is behind you.

3 The constellations on the chart should now match what you see in the sky.

Magnitudes

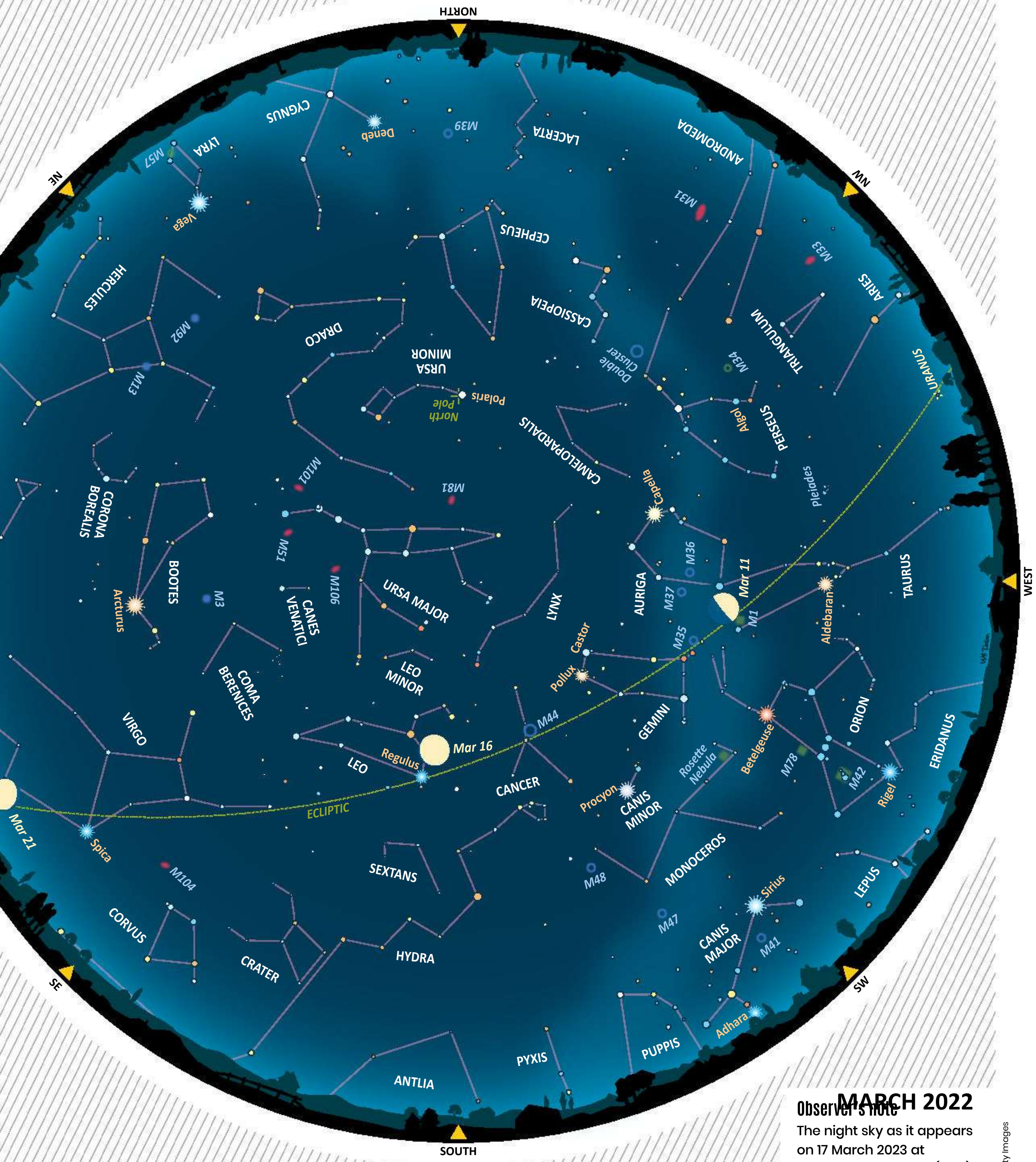
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- ● O-B
- ○ A
- ○ F
- ● G
- ● K
- ● M

Deep-sky objects

- ○ ○ Open star clusters
- ● ● Globular star clusters
- 🟩 🟩 Bright diffuse nebulae
- ○ ○ Planetary nebulae
- Galaxies


NORTH
NE
NW
WEST
SE
SW
SOUTH
CYGNUS
Deneb
M39
LACERTA
ANDROMEDA
LYRA
M57
Vega
M31
CEPHEUS
M33
HERCULES
ARIES
CASSIOPEIA
M92
DRACO
URSA MINOR
Double Cluster
M34
TRIANGULUM
URANUS
M13
Polaris
North Pole
Algol
PERSEUS
CAMELOPARDALIS
M101
M81
Capella
Pleiades
CORONA BOREALIS
M51
M36
M106
URSA MAJOR
Mar 11
BOOTES
M3
CANES VENATICI
LYNX
AURIGA
M37
M1
TAURUS
Arcturus
Aldebaran
M35
Castor
LEO MINOR
Pollux
COMA BERENICES
M44
GEMINI
ORION
VIRGO
Mar 16
ERIDANUS
Regulus
LEO
Rosette Nebula
Betelgeuse
M78
M42
Rigel
CANCER
Procyon
CANIS MINOR
ECLIPTIC
Mar 21
Spica
MONOCEROS
SEXTANS
M48
LEPUS
M104
Sirius
CORVUS
M47
CANIS MAJOR
M41
CRATER
HYDRA
Adhara
PUPPIS
PYXIS
ANTLIA

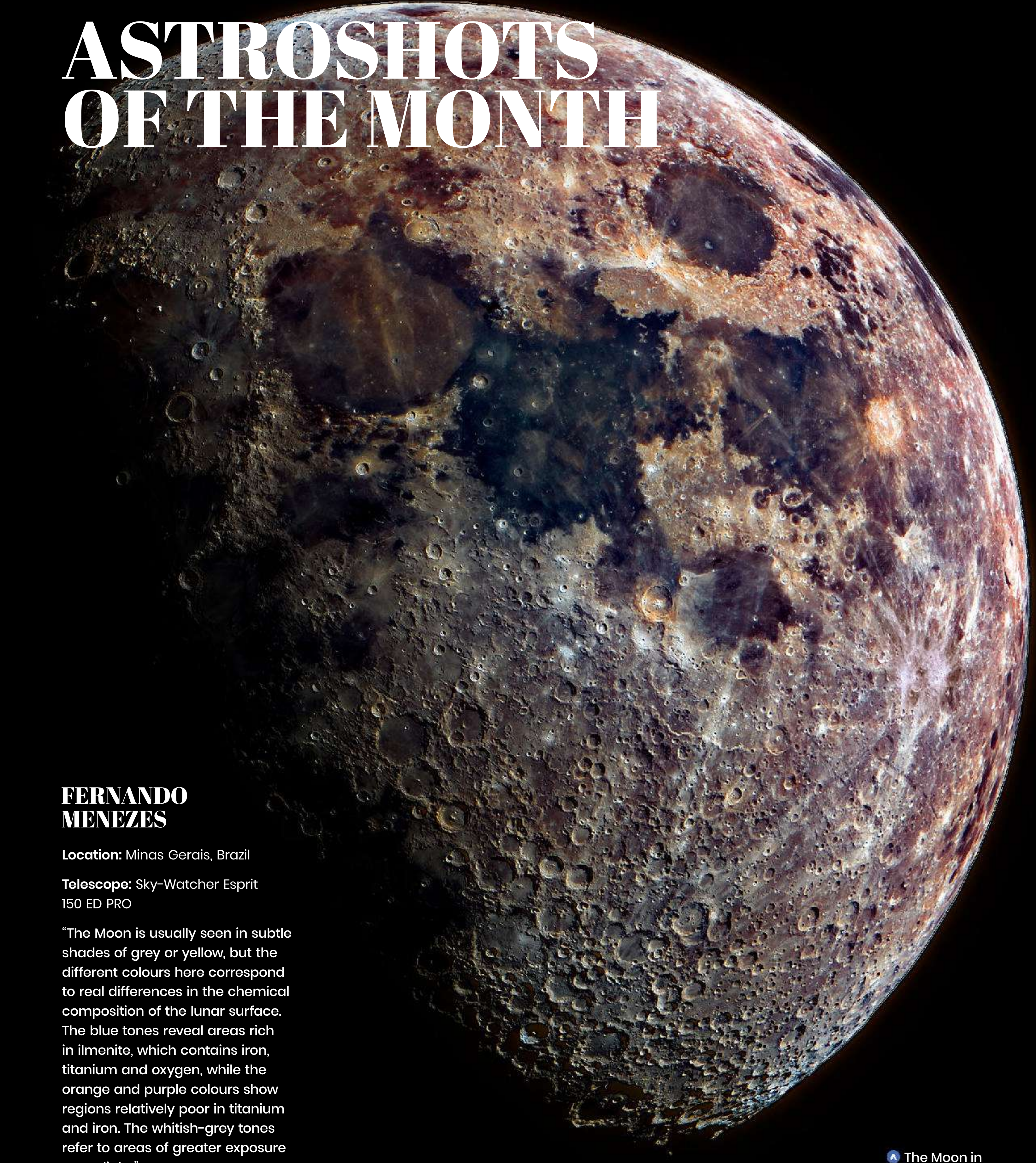
Observer's note

MARCH 2022

The night sky as it appears on 17 March 2023 at approximately 22:00 (GMT)

© Getty Images

ASTROSHOTS OF THE MONTH



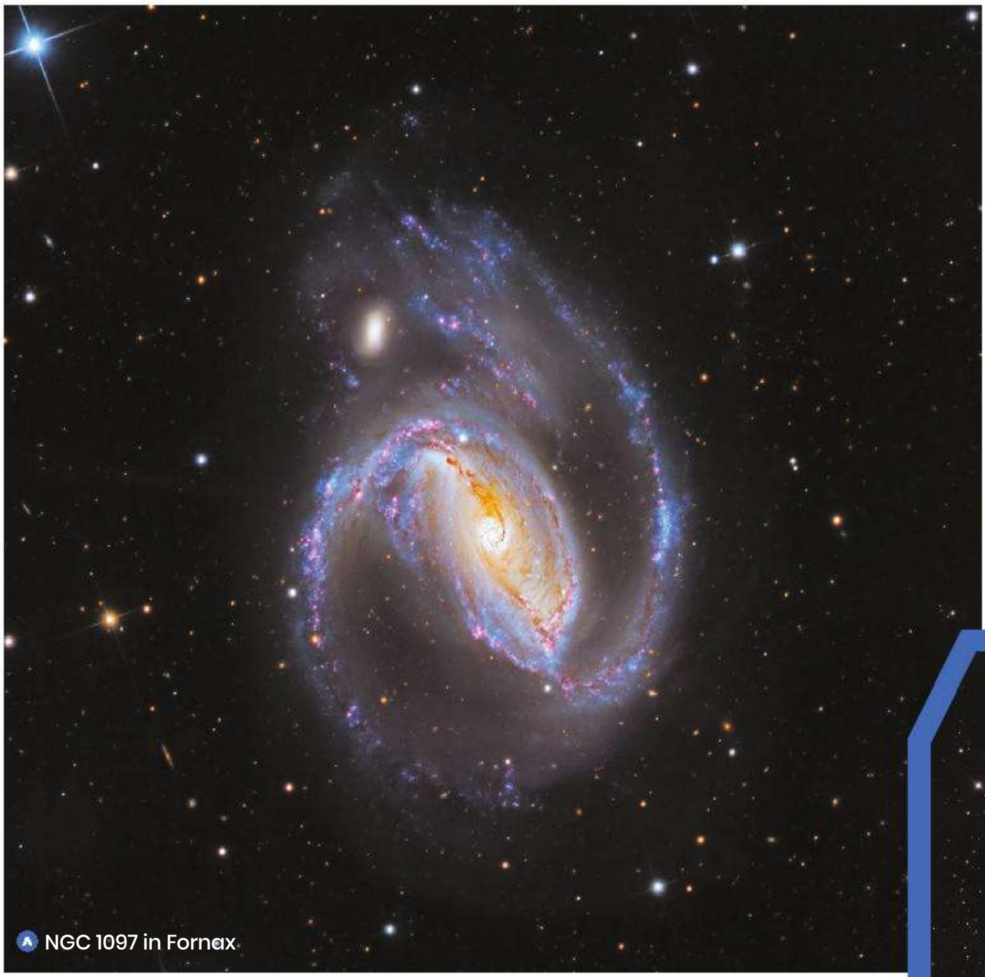
FERNANDO MENEZES

Location: Minas Gerais, Brazil

Telescope: Sky-Watcher Esprit 150 ED PRO

"The Moon is usually seen in subtle shades of grey or yellow, but the different colours here correspond to real differences in the chemical composition of the lunar surface. The blue tones reveal areas rich in ilmenite, which contains iron, titanium and oxygen, while the orange and purple colours show regions relatively poor in titanium and iron. The whitish-grey tones refer to areas of greater exposure to sunlight."

The Moon in 'mineral colours'



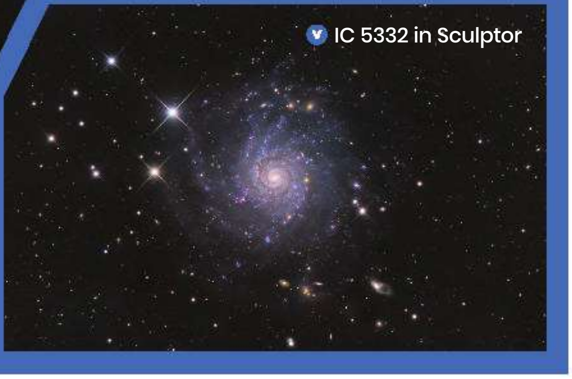
NGC 1097 in Fornax

WARREN KELLER

Location: West Virginia

Telescope: 16-inch RCOS Ritchey-Chrétien owned by the University of North Carolina

"I'm an advanced astrophotographer and teacher and have been published as an author and photographer in many astronomy magazines, as well as many places on the internet, including NASA's Astronomy Picture of the Day. I have also been a consultant for Celestron, where I co-designed AstroFX software for the Nightscape camera. I'm now also a part-time representative for QSI Imaging."



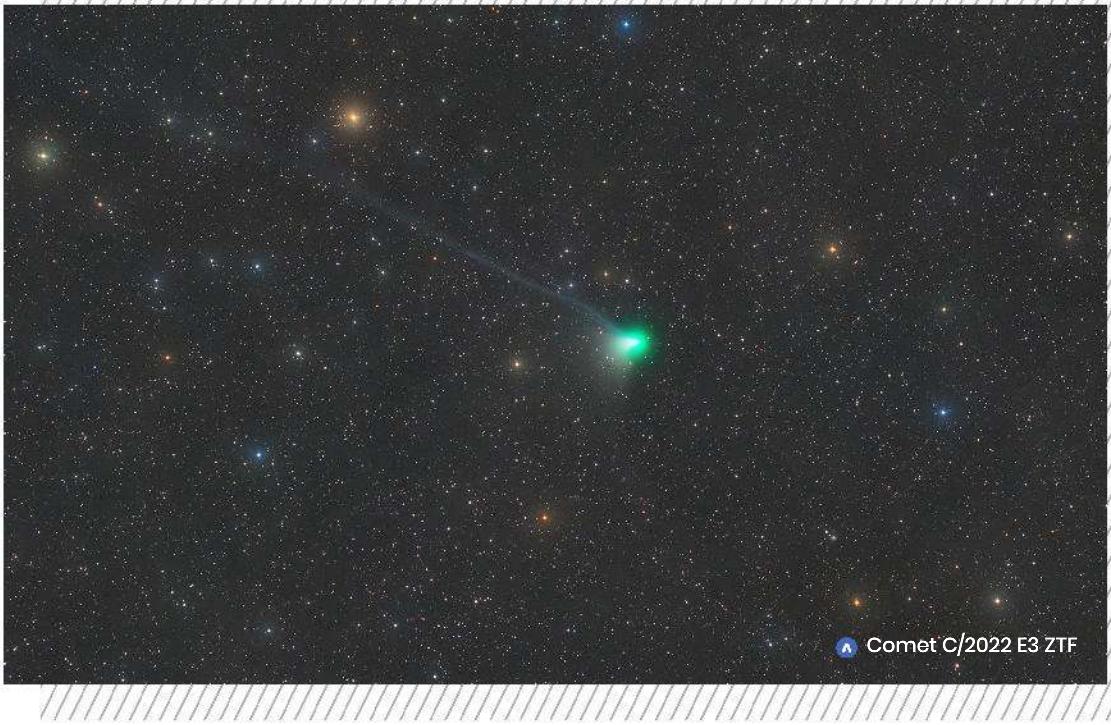
IC 5332 in Sculptor

SOUMYADEEP MUKHERJEE

Location: West Bengal, India, and El Sauce Observatory, Chile

Telescope: Telescope Live

"I'm an amateur photographer from India and have been imaging objects in the sky for the last two years. This image captures the long ion tail of Comet C/2022 E3 ZTF in the night sky as it passes the constellation of Corona Borealis, the Northern Crown. The image was acquired remotely via Telescope Live, which offers online access to a global network of ten robotic telescopes."



Comet C/2022 E3 ZTF

REVIEW

LEGO INTERNATIONAL SPACE STATION

Join the astronauts in orbit with this excellent model

Reviewed by Ian Evenden

We can imagine that the International Space Station (ISS) might be a divisive set among LEGO collectors – we're emphasising 'collector' because this is one of those sets that's definitely not meant to be a toy. For spaceflight fans, the finished model is an excellent representation of the ISS. It's got great stature, with the 49-centimetre (20-inch) central truss and the huge solar arrays adding depth, nicely finished off with a UCS-style plaque. On the other hand, LEGO fans looking for an interesting and stable build might be disappointed.

The International Space Station is part of the LEGO Ideas line, based on a design by LEGO fan Christoph Ruge. It's nicely presented in its box, which has a lift-up lid rather than having to break open a seal at the side.

MODEL ADVICE

Cost: £59.99 / $69.99

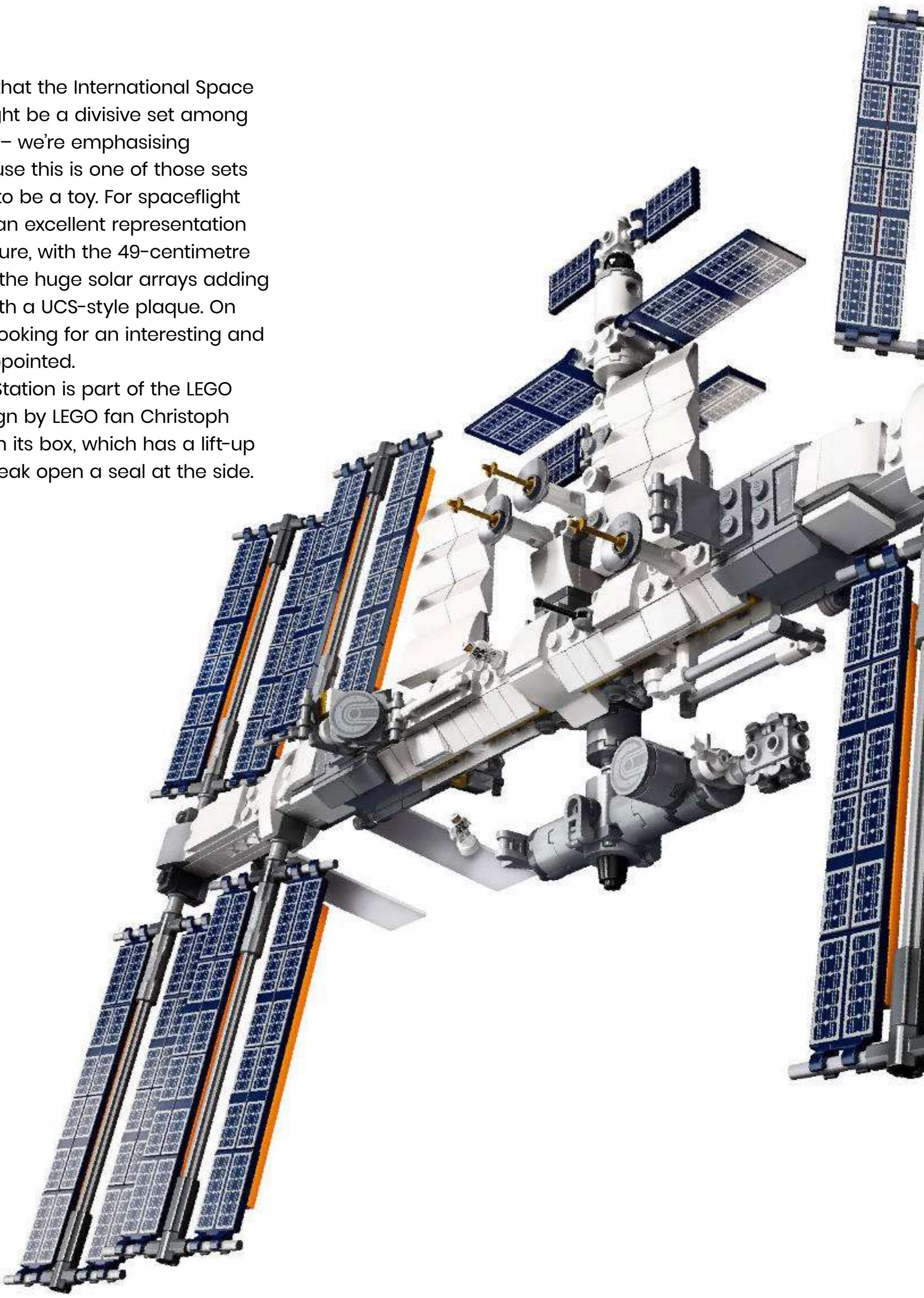
From: LEGO

Model number: 21321

Pieces: 864

Finished dimensions: 49 by 20 by 31 centimetres (20 by 8 by 13 inches)

Recommended age: 16+



This LEGO set is one designed for display rather than play

The box has a lift-up lid for easy opening

LEGO
LEGO
ISS20
LEGO.com/ideas

We tend to find that the boxes with lids and a tray are better for putting all the pieces in while building to avoid accidentally knocking any onto the floor. Inside are six bags of bricks, plus a chunky 128-page manual. In reality, it took more than 40 spaceflights – including 36 Space Shuttle flights – over about a dozen years for astronauts to build the ISS module by module. Now you can build it in a couple of hours, and unlike the real one, you won't have to de-orbit it!

Bag one contains several mini-builds, including a fantastic snub-nosed space shuttle to give you something to swoosh around and a handful of small, simple capsules. Bag two is the stand, which uses a large black 6-by-16 plate as a base and features four stanchions niftily held in place by Technic pins, on top of which sits a cradle to hold the space station.

By this stage, we were becoming eager to actually begin construction of the ISS itself. Bag three contains most of the elements for the station's central truss. We didn't find this to be the most engaging build – it's basically a long white and dark-grey rectangle with no particularly interesting parts.

Things became more interesting with the attachment of the various modules, which are essentially built by skewering them with a Technic rod. The instructions suggest that this stage is best attempted when the truss is attached to the stand, although the station only lightly clasps to the stand by two studs on either side, leaving it prone to easily being dislodged. Adding the

BEST FOR...

- £ MEDIUM BUDGETS
- HOBBYISTS
- FAMILIES

"We did feel a sense of accomplishment as we added the modules, such as the Columbus lab module and Kibō, the Japanese module"

© Jason Parnell-Brookes

modules does leave the model back-heavy, which further adds to the risk of it toppling off the stand.

Printed pieces are one of the highlights of the set. There are docking latches printed on circular two-by-two tiles and tiny airlocks printed on one-by-one circular tiles. There are also the many printed solar arrays on dark-blue tiles, some of which affix to the station's solar panels, while others clip onto the various capsule mini-builds. There's also some neat gold antennae and silver-chromed dishes that will be of interest to the dedicated LEGO builder looking for interesting pieces.

Completing the build are the eight solar panel arrays, which are simple but repetitive builds. However, we found that once these are added they increase the size of the model dramatically, and they are held in place securely by Technic pins that allow them to tilt to face in the direction of the Sun.

LEGO's ISS model looks great. It's got a sense of scale – if we step back and squint at it, we can almost imagine that it's the real thing. And despite the rickety nature of parts of the build, we did feel a sense of accomplishment as we added the modules one by one, such as the Columbus lab module and Kibō, the Japanese module. The ISS' two robotic arms, Canadarm2 and the Japanese Experiment Module Remote Manipulator System are also represented as movable features that can grab one of the mini capsules. There's even a neat cone piece with printed windows to represent the viewing cupola.

One complaint we did have is that there's very little ancillary material. The chunky manual does a great job of providing clear instructions well – although we did spot one error on page 52 in the placement of some 'cheese-slope' pieces – and it also has a little background information about the ISS. However, a little more detail wouldn't have gone amiss. Take the small capsule builds. As spaceflight fans, we know roughly what the capsules are meant to represent – probably a SpaceX Dragon capsule and a couple of Soyuz capsules.

For the uninitiated, however, these builds will be mysterious, and nowhere in the manual does it explain what they are. This lack of information also extends to the various parts of the station. It would have been nice, for example, had the different modules been named in the manual – we had to resort to looking it up online.

LEGO
IDEAS
16+
21321
864 pcs/pzs
INTERNATIONAL SPACE STATION

With 864 pieces, this build will require a bit of dedication

> "Printed pieces are one of the highlights of the set. There are docking latches and tiny airlocks printed on tiles"

Still, even though the various modules remain nameless within the kit, there's lots of detail in the model, with antennae, communication dishes, airlocks, robot arms, heat exchangers and various scientific experiments set up on the space station's hull. Although you can't really play with the model, visually there's lots to inspect on it.

Overall, we found that the finished International Space Station looks highly impressive and is a great and surprisingly accurate representation of the ISS. For the price it really is a large model, so we felt like we got our money's worth – although it's so large and unwieldy that finding a safe place to display it can be tricky! We'd definitely recommend it to any space fan with an interest in LEGO or model building.

FOR

- ⊕ Great shelf presence
- ⊕ Good price
- ⊕ Excellent mini-shuttle
- ⊕ No stickers

AGAINST

- ⊖ Doesn't stay on the stand well, prone to coming apart
- ⊖ No explanation of the various parts of the station
- ⊖ Uninvolving and at times repetitive build

©LEGO

Future Genius

THE BRAND NEW

EDUTAINMENT BOOKS FOR KIDS!

For ages 7+

OUT NOW!

on sale now

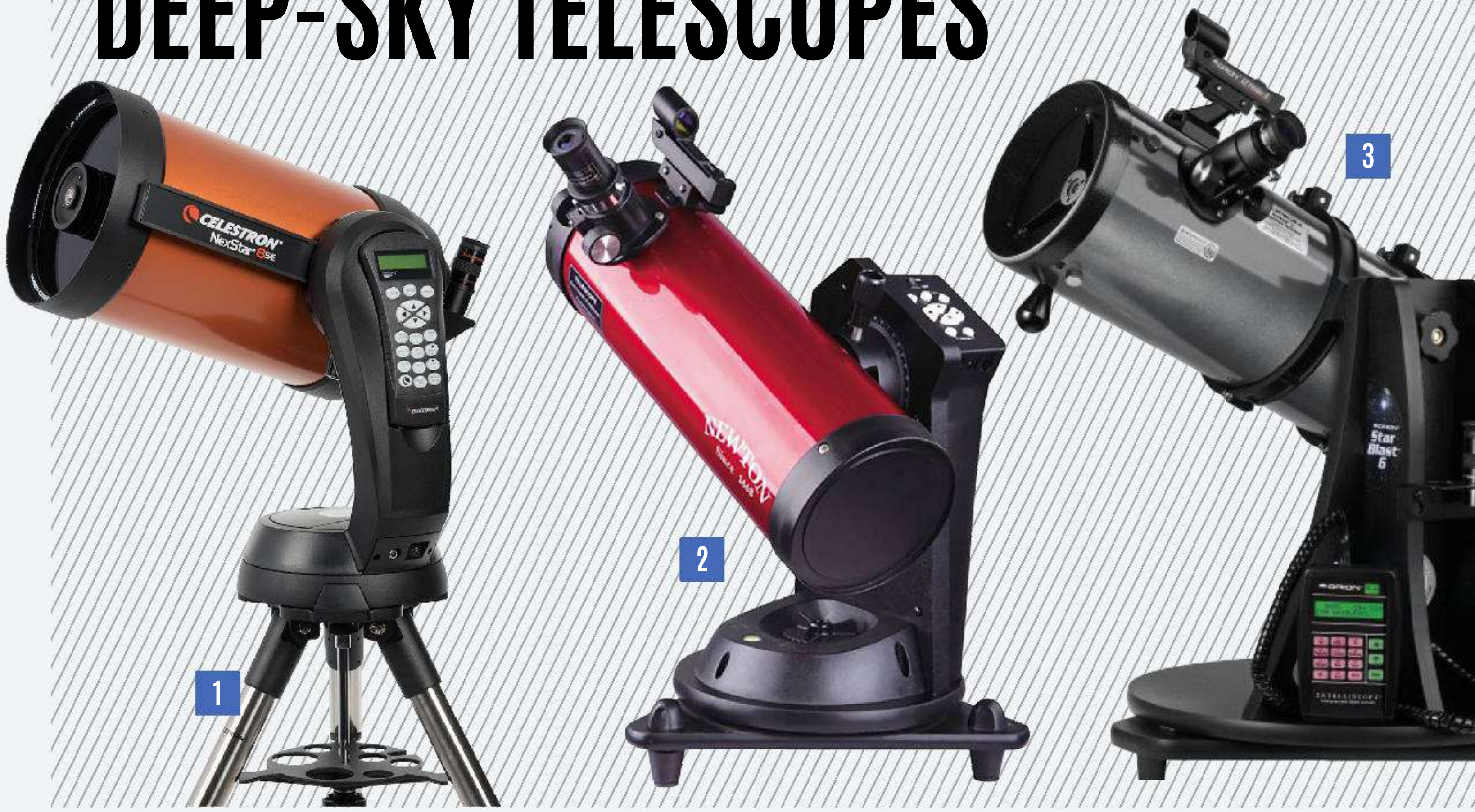
★ Solar System ★ Cool Chemistry ★ Human Body
★ Animal Kingdom ★ Ancient Egyptians
★ Computers & Learn to Code ★ Weather
★ Ancient Greece ★ Dinosaurs ★ The Senses
★ The World ★ Magical Maths ★ Bugs ★ The Universe

WATCH VIDEOS WITH OUR INCREDIBLE INTERACTIVE EXPERIENCE

GET YOURS NOW FROM MAGAZINESDIRECT.COM
AND ALL GOOD SUPERMARKETS AND NEWSAGENTS

✚ Puzzles ✚ Activities ✚ Experiments ✚ Facts ✚ More!

IN THE SHOPS: DEEP-SKY TELESCOPES



Celestron NexStar 8SE

Cost: £1,499 (approx. $1,799.90)
From: Celestron

1 One of the most striking things about the Celestron NexStar 8SE is its compact and practical size, despite offering a long focal length. The body is clutter-free, so you can easily pick it up and transport it to where it's needed without worrying about breaking anything or accidentally snapping things off. It's fairly heavy, but that gives it a robust and sturdy feel – much appreciated when you're spending this sort of money. The telescope is controlled using an in-built hand controller. We also liked the feeling of using the hands-on controller with tactile, easy-to-use buttons rather than having to rely on a smartphone app. Astrophotographers taking long exposures will love the smooth and accurate tracking thanks to the mount's high-quality motorised functionality.

Sky-Watcher Heritage 114P Virtuoso

Cost: £239 (approx. $286.95)
From: Sky-Watcher

2 Despite its diminutive size and light weight, the Heritage 114P isn't lacking in features. It offers the whole Newtonian reflector experience, with the added benefit of being able to automatically counteract the rotation of Earth and track the sky. With the mount's AA battery or DC-powered motors switched on, you can smoothly slew across the sky using the built-in controls and then steadily keep your object of interest in the field of view. The tabletop Dobsonian mount can be upgraded at any time with Sky-Watcher's SynScan GoTo handset. This can find more than 40,000 objects in the sky for you – useful for tracking down those very faint sights that don't readily jump out.

Orion StarBlast 6i IntelliScope

Cost: £477.99 / $483
From: Orion

3 The StarBlast 6i is capable of resolving stars in brighter globular clusters as well as the structures of planetary nebulae. The supplied eyepieces provide good starting points for exploring a range of deep-sky objects, including large emission nebulae and compact clouds. The included red-dot finder is a slight drawback to the overall package, but it uses a standard dovetail mounting shoe and can be upgraded to an optical finder anytime. The StarBlast 6i's unique selling point is its intelligent push-to Dobsonian mount, which is not only compact and sturdy, but capable of helping you navigate the stars to find more than 14,000 objects. With built-in encoders and a handset using just a single nine-volt battery, it directs you to manually slew the telescope to find whatever you're looking for.

> "It's a superb-value proposition for those on a budget"

4
5
6
Sky-Watcher
CLASSIC 200P
UNISTELLAR
CELESTRON
ORION

Sky-Watcher Skyliner 200P

Cost: £379 (approx. $455.10)
From: Sky-Watcher

4 The Skyliner 200P is the most affordable way to enjoy deep-sky astronomy at this standard. Its basic Dobsonian mount can't find or track objects in the sky for you, but with smooth mechanics, you'll have no trouble doing this by hand the old-fashioned way. The 50-millimetre finder, a small telescope in its own right, is ideally suited to finding and centring objects of interest before investigating them with the sizable main mirror. The telescope also features a dual-size focuser that can accept two-inch eyepieces, a must for anyone seeking the most immersive deep-sky views. While it's somewhat bulky at nearly 24 kilograms, the Skyliner 200P has a fairly small footprint of about 54 centimetres (21 inches). It's a superb-value proposition for those on a budget looking to do serious deep-sky work.

Unistellar eVscope 2

Cost: £3,999 / $4,899
From: Unistellar

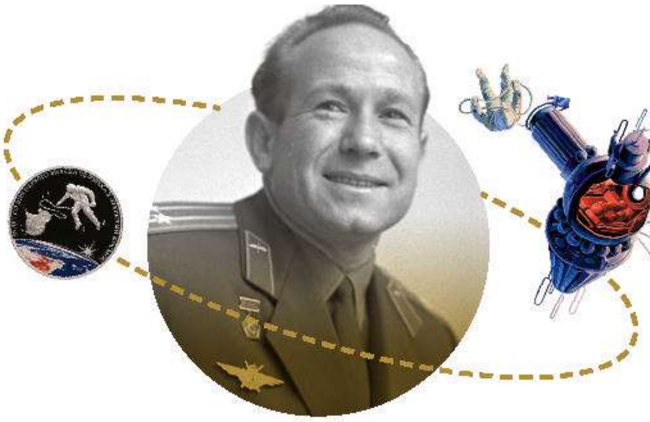
5 The eVscope 2 – the newer version of the eQuinox – offers a very different way to 'see' the night sky. As a beginner, you can navigate the night sky in no time. The eVscope 2 uses a camera instead of an eyepiece, similarly to the original eQuinox, but it also has a Nikon eyepiece which will appeal to purist astronomers and clubs who don't want to 'see' the sky through the Unistellar app on a smartphone. It is straightforward to navigate the night sky at the touch of a button, even with no prior astronomy knowledge. In Explore mode, the app will recommend celestial objects based on your location and time zone. You need your phone or smart device to operate the telescope, so ensure you've charged both up before exploring.

Celestron Advanced VX 8" EdgeHD

Cost: £2,549 (approx. $3,060.60)
From: Celestron

6 The EdgeHD employs a widely acclaimed optical tube assembly as the basis for a very capable overall system. The StarSense camera not only aligns the telescope for you, but also connects to Celestron's SkyPortal app via the telescope's Wi-Fi. This is all powered by a substantial rechargeable battery built into the mount – no cables or external power supply required. All this comes at a cost, but if you want a home observatory that sets itself up and takes you on a tour of the sky, it's a fair price. The Schmidt-Cassegrain is expensive for its aperture, but it's extremely compact, employing two mirrors and a corrector plate to fold its long focal length into a shorter tube. The optics are among the best in class at this price point.

HEROES OF SPACE



ALEXEI LEONOV

The first man to walk in space

Born in Siberia on 30 May 1934, Leonov graduated from a selection of air force academies with honours and was quickly picked to be one of the first 20 people for the Soviet space program. In 1965 the Soviet Union was well ahead of the US in the race to land humans on the Moon: they had already launched the first satellite, animal, man and woman into space. When the Soviet Union learned that the US was planning the first spacewalk, their efforts became focused on beating them to it. Leonov underwent 18 months of intensive weightlessness training, and while the US spacewalk was scheduled for June, Leonov was first blasted into orbit on 18 March 1934.

Leonov shared the two-man Voskhod with Pavel Belyayev. Once it had completed one orbit, he was given the all clear to begin his historic walk. He crawled into the airlock, opened the hatch, slid out and floated into space. The defining memory for Leonov, as he would later recount, was the all-encompassing silence of space, "It was so quiet I could even hear my heart beat. I was surrounded by stars and was floating without much control. I will never forget the moment. I also felt an incredible sense of responsibility." For 12 minutes and nine seconds the cosmonaut conducted the first-ever spacewalk while connected to the spacecraft by a 5.4-metre (17.6-feet) tether.

However, Leonov's true test of skill came when he attempted to return to the ship. Experts hadn't foreseen the effect the vacuum of space would have on the cosmonaut's suit – it was steadily inflating. As the difference in air pressure caused the suit to balloon out of shape, Leonov's hands were pushed out of the gloves and his feet out of his boots. In fact, the suit had ballooned so much that he was unable to return through the airlock. To add even more danger, he only had five minutes before the craft would enter Earth's shadow and be plunged into total darkness.

Acting quickly, Leonov bled some air out of the suit by opening a valve. The suit slowly deflated. Just in time, Leonov managed to force himself through the airlock headfirst and close the hatch behind him. However, Leonov's troubles were far from over: as the capsule attempted to re-enter Earth's atmosphere, it malfunctioned. After an emergency landing, Leonov and Belyayev found themselves 965 kilometres (600 miles) off course in a remote area of the Ural mountains. For two freezing nights the men waited in temperatures below zero before they were finally rescued. The Soviet Union were quick to celebrate the mission as a success, but it very nearly ended in disaster.

Passing away on 11 October 2019 at the age of 85 in Moscow, Russia, Leonov was hailed as a Hero of the Soviet Union for his spacewalk.

© Alamy; Getty Images; Dorling Kindersley

ALL ABOUT SPACE
ISSUE 141
ON SALE
23 MARCH

ALL ABOUT SPACE

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Content Director **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**

Contributors
Jim Al-Khalili, Stuart Atkinson, Harry Baker, Andrew Barton, Lee Cavendish, David Crookes, Briony Duguid, Christopher J. Ferguson, Robin Hague, Elizabeth Howell, Andrew Jones, Sharmila Kuthunur, Robert Lea, Samantha Mathewson, Paul McNamara, Simon Morden, Jonathan O'Callaghan, Jeremias Pfaff, Meredith Rawls, Elizabeth Rayne, Ryan Wells

Cover images
Getty; NASA; Tobias Roetsch

Photography
Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons;
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Manager **Matthew Johnson**
matthew.johnston@futurenet.com
07974 408 083
Account Manager **Hayley Brailey-Woolfson**
hayley.braileywoolfson@futurenet.com
01643 678 054

International Licensing and Syndication
All About Space is available for licensing and syndication. To find out more contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas orderline & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
Group Marketing Director, Magazines & Memberships **Sharon Todd**
Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Ben Oakden**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Senior Advertising Production Manager **Jo Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Nick Williams**

Management
SVP Lifestyle, Knowledge and News **Sophie Wybrew-Bond**
Managing Director **Chris Kerwin**
Content Director **Gemma Lavender**
Editor-in-Chief **Timothy Williamson**
Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

All contents © 2023 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

Widely Recycled

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

FUTURE
Connectors. Creators. Experience Makers.

Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief Executive **Zillah Byng-Thorne**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

ipso. Regulated

IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE

When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepoint. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepoint for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. Thank you.

Text PLACE to 78866 to donate £3

Call free on 0800 472 5798

Visit centrepoint.org.uk/place

Or complete and return the form below

centre point

SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

Instruction to your Bank or Building Society to pay by Direct Debit DIRECT Debit

To the Manager:
Name and full address of your Bank or Building Society:

Originators Identification No. 6 5 9 1 0 7

Postcode ______

Name(s) of Account Holder(s) ______

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) ______ Date ______

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

Increase your donation by 25p for every £1 you donate with Gift Aid giftaid it

☐ By ticking this box I confirm I am a UK taxpayer and want Centrepoint to Gift Aid all donations I've made in the last four years and any donations I make in the future until I notify you otherwise. I understand that if I pay less Income Tax and/or Capital Gains Tax in any tax year than the amount of Gift Aid claimed on all my donations it is my responsibility to pay any difference.

Your name and address are needed to identify you as a current UK taxpayer.

Your donation will go towards funding Centrepoint's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.

Registered Charity No 292411.

NAP2021CN

Full Name: ______
Address: ______

Postcode: ______ Telephone: ______
Email: ______

Thank you for donating to Centrepoint today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

☐ **Please contact me by email** ☐ **Please contact me by phone**

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

Your privacy is key.

We promise never to sell or swap your details, and will always keep them secure. You can view our Privacy Notice in full at www.centrepoint.org.uk/privacy. You can opt out of post and change how we communicate with you at any time. Please call 0800 232320 and speak to one of our friendly team or email supportercare@centrepoint.org to do this and ask us any questions.

Please return this form to: Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.

Registered office address: Central House, 25 Camperdown Street, London E1 8DZ. Company no. 1929421. Registered Charity no. 292411. Housing association no. H1869. VAT registration no. 649 345 018.

Registered with FUNDRAISING REGULATOR

centre point give homeless young people a future

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE TELESCOPES

"This telescope made observing the night sky enjoyable….great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

Sky at Night Magazine GROUP TEST WINNER

ASTROLUX
76mm f/9.2 REFLECTOR
SRP £115

Sky at Night Magazine GROUP TEST WINNER

MERCURY-707
70mm f/10 REFRACTOR
SRP £129

CAPRICORN-70 (EQ1)
70mm f/12.8 REFRACTOR
SRP £159

"Meets all expectations and is the perfect starter scope"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-130 (EQ2)
130mm f/6.9 REFLECTOR
SRP £229

SKYHAWK-1145P (EQ1)
114mm f/5 PARABOLIC REFLECTOR
SRP £199

EXPLORER-130P (AZ-GO2)
130mm (5.1") f/5 Wi-Fi GO-TO Parabolic Reflector
SRP £379

SKYHAWK-1145P (AZ-GO2)
114mm (4.5") f/4.4 Wi-Fi GO-TO Parabolic Reflector
SRP £319

SKYMAX-127 (AZ-GO2)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain
SRP £499

SKYMAX-127 (AZ-GTI)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain
SRP £629

Sky at Night Magazine ★★★★★ REVIEWED IN Issue 152 January 2018

STAR DISCOVERY P150I 150mm (6")
f/5 Wi-Fi GO-TO Parabolic Reflector
SRP £559

EXPLORER-150P (EQ3-2)
150mm f/5 PARABOLIC REFLECTOR
SRP £489

Sky at Night Magazine HIGHLY COMMENDED 87%

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR
SRP £735

Sky at Night Magazine GROUP TEST WINNER

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN
SRP £439

Sky at Night Magazine HIGHLY COMMENDED 93%

SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN
SRP £649

HERITAGE-150P FLEXTUBE™ (VIRTUOSO GTI)
150mm f/5 Wi-Fi GO-TO PARABOLIC DOBSONIAN
SRP £419

SKYMAX-127 (VIRTUOSO GTI)
127mm f/11.8 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN
SRP £575

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN
SRP £215

HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN
SRP £269

THE ESSENTIAL *Optical Product Guide*

Email for 88 Page **FREE** Catalogue

Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

9021

9000